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EUROPEAN REFUSE FIRED ENERGY SYSTEMS
EVALUATION OF DESIGN PRACTICES

Zurich: Hagenholz
Switzerland

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Volume 8

U.S. ENVIRONMENTAL PROTECTION AGENCY

1979

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An environmental protection publication (SW-176c.8) in the solid waste management series.

TRIP REPORT

to

ZURICH: HAGENHOLZ, SWITZERLAND

(FEATURING UNIT #3 AND COMMENTING ON
THE NEW JOSEFSTRASSE PLANT)

on June 8, 9, and 10, 1977

on the contract

EVALUATION OF EUROPEAN REFUSE FIRED STEAM GENERATOR DESIGN PRACTICES

to

U.S. ENVIRONMENTAL PROTECTION AGENCY

December 20, 1977

EPA Contract Number: 68-01-4376
Battelle Project Number: G-6590
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PREFACE

This trip report is one of a series of 15 trip reports on European waste-to-energy systems prepared for the U.S. Environmental Protection Agency. The overall objective of this investigation is to describe and analyze European plants in such ways that the essential factors in their successful operation can be interpreted and applied in various U.S. communities. The plants visited are considered from the standpoint of environment, economics and technology.

The material in this report has been carefully reviewed by the European grate or boiler manufacturers and respective American licensees. Nevertheless, Battelle Columbus Laboratories maintains ultimate responsibility for the report content. The opinions set forth in this report are those of the Battelle staff members and are not to be considered by EPA policy.

The intent of the report is to provide decision making information. The reader is thus cautioned against believing that there is enough information to design a system. Some proprietary information has been deleted at the request of vendors. While the contents are detailed, they represent only the tip of the iceberg of knowledge necessary to develop a reliable, economical and environmentally beneficial system.

The selection of particular plants to visit was made by Battelle, the American licensees, the European grate manufacturers, and EPA. Purposely, the sampling is skewed to the "better" plants that are models of what the parties would like to develop in America. Some plants were selected because many features envolved at that plant. Others were chosen because of strong American interest in co-disposal of refuse and sewage sludge.

The four volumes plus the trip reports for the 15 European plants are available through The National Technical Information Service, Springfield, Virginia 22161. NTIS numbers for the volumes and ordering information are contained in the back of this publication. Of the 19 volumes only the Executive Summary and Inventory have been prepared for wide distribution.

ORGANIZATION

The four volumes and 15 trip reports are organized the the following fashion:

VOLUME I

A EXECUTIVE SUMMARY
B INVENTORY OF WASTE-TO-ENERGY PLANTS
C DESCRIPTION OF COMMUNITIES VISITED
D SEPARABLE WASTE STREAMS
E REFUSE COLLECTION AND TRANSFER STATIONS
F COMPOSITION OF REFUSE
G HEATING VALUE OF REFUSE
H REFUSE GENERATION AND BURNING RATES PER PERSON
I DEVELOPMENT OF VISITED SYSTEMS

VOLUME II

J TOTAL OPERATING SYSTEM RESULTS
K ENERGY UTILIZATION
L ECONOMICS AND FINANCE
M OWNERSHIP, ORGANIZATION, PERSONNEL AND TRAINING

VOLUME III

P REFUSE HANDLING
Q GRATES AND PRIMARY AIR
R ASH HANDLING AND RECOVERY
S FURNACE WALL
T SECONDARY (OVERFIRE) AIR

VOLUME IV

U BOILERS
V SUPPLEMENTARY CO-FIRING WITH OIL, WASTE OIL AND SOLVENTS
W CO-DISPOSAL OF REFUSE AND SEWAGE SLUDGE
X AIR POLLUTION CONTROL
Y START-UP AND SHUT-DOWN
Z APPENDIX

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Herr Puli	Hagenholz Assistant Operations Manager

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SUMMARY

This report discusses the Zurich: Hagenholz refuse fired steam generation plant. Units #1 and #2 are only occasionally mentioned. Unit #3 was manufactured by Martin and is featured in the discussion. The report also refers to the two older Josefstrasse plants (now demolished) and the new Josefstrasse plant by Martin due to begin operations in 1979. All plants and units are described to present the picture of the refuse fired steam generation (RFSG) technology as it evolved in Zurich.

The Hagenholz plant is located in the Zurich suburb of that name. In 1976, all three units burned about 218,342 tonnes (240,176 tons) as collected from a 560,000 person area. It was a surprise to many that the lower heating value had doubled since the end of World War II. This has had both negative and positive effects on plant operations.

The plant is owned and operated by Abfuhrwesen, the City of Zurich's Department for Refuse Collection and Disposal.

Abfuhrwesen collects about 56% of the plants input while 18% comes from other municipalities and 26% from private haulers and businesses.

In addition to municipal solid waste, the plant also receives waste oil, waste solvents, and other chemicals.

Ajoining the RFSG plant is a new rendering plant also under the control of Abfuhrwesen. A delightful feature is that odiferous rendering gases are collected and injected into the RFSG furnaces as secondary air. No objectional odor is thus emitted from either plant.

Zurich began converting waste to energy almost 75 years ago (1904) at Josefstrasse. A second Josefstrasse plant was built in 1927. Hagenholz Units #1 and #2 were operational in 1969. Hagenholz Unit #3 started in 1973. Now the third Josefstrasse unit is due to begin in 1979.

Unit #3 is routinely stopped every 1000 hours for eight hours to conduct inspections. The unit is also stopped every 4,000 hours for major inspection and repair. An excellent set of steam and temperature readings over the 4000 hour cycle have been provided by the plant personnel.

While the entire Hagenholz plant burns 570 to 700 tonnes per day, Unit #3 burns 240 to 450 tonnes per day. Household waste and bulky waste that has been sheared are fed into the furnaces.

Both the primary (underfire) air and the secondary (overfire) air are injected into the furnace at very high pressures, overfire air at 500 to 700 mmWs (20 to 28 inches). This produces an intense flame.

The Martin reverse action reciprocating grate has performed well and still has 70% of the original grate bars intact after 30,000 hours (3-1/2 years).

The "   boiler" can also be described as a "one-drum natural circulation boiler with welded water tube walls". The layout of superheaters is routine compared to Martin's layout at Josefstrasse that has the hottest steam superheater bundle in the second position behind another superheater section.

Readings are provided for much of one day when a bulky load greatly reduced flue gas temperatures and the quantity of steam produced. However, steam temperature and pressure remained perfectly constant.

The furnace water tube walls, which are part of the boiler, are covered with small steel studs (2,000 studs/m^2) and then coated with plastic silicon carbide. This is only one of the 33 discussed ways in which planners designed Hagenholz so that metal wastage could be reduced. The combined efforts have been most successful in preventing corrosion and erosion. After 30,000 hours, the water tube walls have suffered only 0.1 to 0.2 mm wastage. The superheater tube readings taken in April, 1977 showed 0.3 mm wastage.

The superheater is equipped with an attemperator or desuperheater to reduce temperatures when the superheated steam becomes too hot. Among the boiler cleaning techniques are compressed air soot blowing, falling steel shot, pneumatic vibrators, manual alkali washing and sandblasting. Each technique is apparently used properly at its unique location. Detailed water quality measurements are taken.

In addition to the three refuse fired units, there is also a No. 2 fuel oil unit to provide start-up steam and to reduce dew point corrosion. Finally, there is a separate waste oil boiler to consume the community's automobile waste oil and to produce energy.

The energy utilization picture is most complex. High temperature steam passes through a steam extraction-condensing turbo generator. Medium temperature steam and hot water are used for three-district heating networks. Electricity is used internally and sold to the two electricity networks.

The plant produces 2.41 tonnes of steam per tonne of refuse. District heating has a priority over electricity production. Therefore, electrical production peaks in the Summer.

All three units have electrostatic precipitators (ESP). Units #1 and #2 have somewhat ineffective multi-cyclone mechanical collectors to supplement their ESP's. Unit #3 was last measured at 42 mg/Nm^3 which is substantially under the 100 mg/Nm^3 requirement of the Swiss government.

Ash recovery is advanced at Hagenholz. Unprocessed ash was 25.8% of the refuse input in 1976. Of the unprocessed ash, only 4% is eventually landfilled. This means that of the refuse received, about 99% is recovered in some fashion. In other words, the landfill life is increased 100 fold with the RFSG and the ash recovery program.

The strong management at Hagenholz is outstanding and memorable. The care devoted to specifying Unit #3 has been rewarded by a most successful plant. There has been a reduction of 100 people in the last seven years from the entire Abfuhrwessen collection and disposal staff.

The entire Hagenholz facility has been built at a capital cost of SF 59,700,000. Of this, the Martin chute-to-stack capital cost in 1972-73 was SF 11,430,000.

The accounting formula for this "not-for-profit" activity defines expenses to equal revenues and for 1976 they both equaled SF 14,424,262. In 1976, U.S. dollars assuming one dollar equals SF 2.50, the plant had expenses and revenues of $24.11 per ton.

The tipping fees accounted for about 53% while the energy sales represented 42% of total revenue. As is often the case, a plant (Hagenholz) that can manufacture energy for both district heating and electrical purposes finds the energy economics much better if it concentrates on district heating and makes electricity as a secondary product.

The plant was financed at three government levels--City (70%), State (15%), and Federal (15%). The Federal 15% carried a stipulation that the plant must successfully pass environmental tests before the Federal share could be released.

STATISTICAL SUMMARY

Community description:	
Area	City Zurich
Population (number of people)	388,165 in Zurich, 560,000 total
Key terrain feature	hills
Solid waste practices:	
Total waste generated per day (tonnes/day)	(610 t/d: total)
Waste generation rate (Kg/person/year)	295
Lower heating value of waste (Kcal/kg)	Design data (Unit #3); 1600-3300 Kcal/kg
Collection period (days/week)	5
Cost of collection (local currency/tonne)	
Use of transfer and/or pretreatment (yes or no)	Shear for bulky wastes
Distance from generation centroid to:	
Refuse fired steam generator (kilometers)	5
Waste type input to system	municipal solid waste
Cofiring of sewage sludge (yes or no)	No
Development of the system:	
Date operation began (year)	Von-Roll furnaces: July 1969 Units #1&#2 Martin : July 1973 Unit #3
Plant architecture:	
Material of exterior construction	concrete
Stack height (meters)	91
Refuse fired steam generator equipment:	
Mass burning (yes or no)	Yes
Waste conditions into feed chute:	
Moisture (percent)	20-25%
Lower heating value (Kcal/kg)	2200-2400
Volume burned:	
Capacity per furnace (tonnes/day) design:	Martin 473 t/d at LHV = 1600 kcal/hg 360 t/d at LHV = 2200 " " 264 t/d at LHV = 3000 " " 240 t/d at LHV = 3300 " "
Number of furnaces constructed (number)	3 2 Von Roll 1 Martin

STATISTICAL SUMMARY (Continued)

Capacity per system (tonnes/day)	570 to 700 tonnes/day
Actual per furnace (tonnes/day)	Unit #3: 240 to 450 tonnes/day
Number of furnaces normally operating (number)	3
Actual per system (tonnes/day)	610 tonnes/day
Use auxiliary reduction equipment (yes or no)	Yes-shear
Pit capacity level full:	
(m^3)	5000
Crane capacity:	
(tonnes)	3.3 tonnes
(m^3)	bucket: 3 m^3
Feeder drive method	hydraulic
Burning grate:	
Manufacturer	Joseph Martin Feuerungsbau GmbH
Type	Reverse Action Reciprocating Grate
Number of sections (number)	3
Length overall (m)	8.35
Width overall (m)	5.57
Primary air-max (Nm^3/hour)	62,000
Secondary air-overfire air-max (Nm^3/hour)	16,000
Furnace volume (m^3)	472
Furnace wall tube diameter (cm)	5.7
Furnace heating surface (m^2)	1,349
Auxiliary fuel capability (no)	
Use of superheater (yes or no)	Yes
Boiler	
Manufacturer	EVT Stuttgart
Type	one-drum natural circulating boiler with welded water tube walls
Number of boiler passes (number)	4
Steam production per boiler (kg/hr)	Max: 38,200 (in 1976: 34,430)
Total plant steam production (kg/hr)	72,000
Steam temperature (° C)	420
Steam pressure bar	38

STATISTICAL SUMMARY (Continued)

Use of convection section (yes or no)	No	
Use of economizer (yes or no)	Yes	
Use of air preheater (yes or no)	Yes	
Use of flue gas reheater (yes or no)	No	
Cofire (fuel or waste) input	No	
Use of electricity generator (yes or no)	Yes	
Type of turbine	condensation, extraction	
Number of turbines (number)	2	
Steam consumption (kg/hr)	2 x 30 tonnes/hour	
Electrical production capacity per turbine (kw)	2 x 6 MW	
Total electrical production capacity (kw)	12 MW	
Turbine back pressure (kg/m^2)		
User of electricity ("Internal" and/or "External")	Internal: 36% External: 64%	
Energy Utilization:		
Medium of energy transfer	Steam	Hot water
Temperature of medium (° C)	260-280	130
Population receiving energy (number)		
Pressure of medium (kg/m^2)		
Energy return medium	Condensate	Warm water ~100° C
Pollution control:		
Air:		
Furnace exit conditions		
Gas flow rate (m^3/hr)	95,580 Nm^3/hr	
Furnace exit loading (mg/Nm^3)		
Equipment:		
Mechanical cyclone collector (yes or no)	No	
Electrostatic precipitator (yes or no)	Yes	

STATISTICAL SUMMARY (Continued)

Manufacturer	ELEX
Inlet loading to precipitator (mg/Nm^3)	
Exit - loading from precipitator (mg/Nm^3)	62-75 mg/Nm^3 (7% CO_2)
Legislative requirement (mg/Nm^3)	100 mg/Nm^3 (7% CO_2)
Scrubber (yes or no)	No
Legislative requirements (mg/Nm^3)	75 mg/Nm^3 adjusted to 7% CO_2
Other air pollution control equipment (yes or no)	
Water:	
Total volume of waste water (liters/day)	32,400
Ash: (1976)	
Volume of ash (tonnes/year)	56,271
Volume of metal recovered (tonnes/year)	6,494

OVERALL SYSTEM SCHEMATIC

The overall schematic for Zurich: Hagenholz is shown in Figure 8-1. This page shows cross-sectional views of both the Von Roll Units #1 and #2 as well as the Martin Unit #3. A detailed picture of the Martin Unit #3 furnace and boiler follows in Figure 8-2.

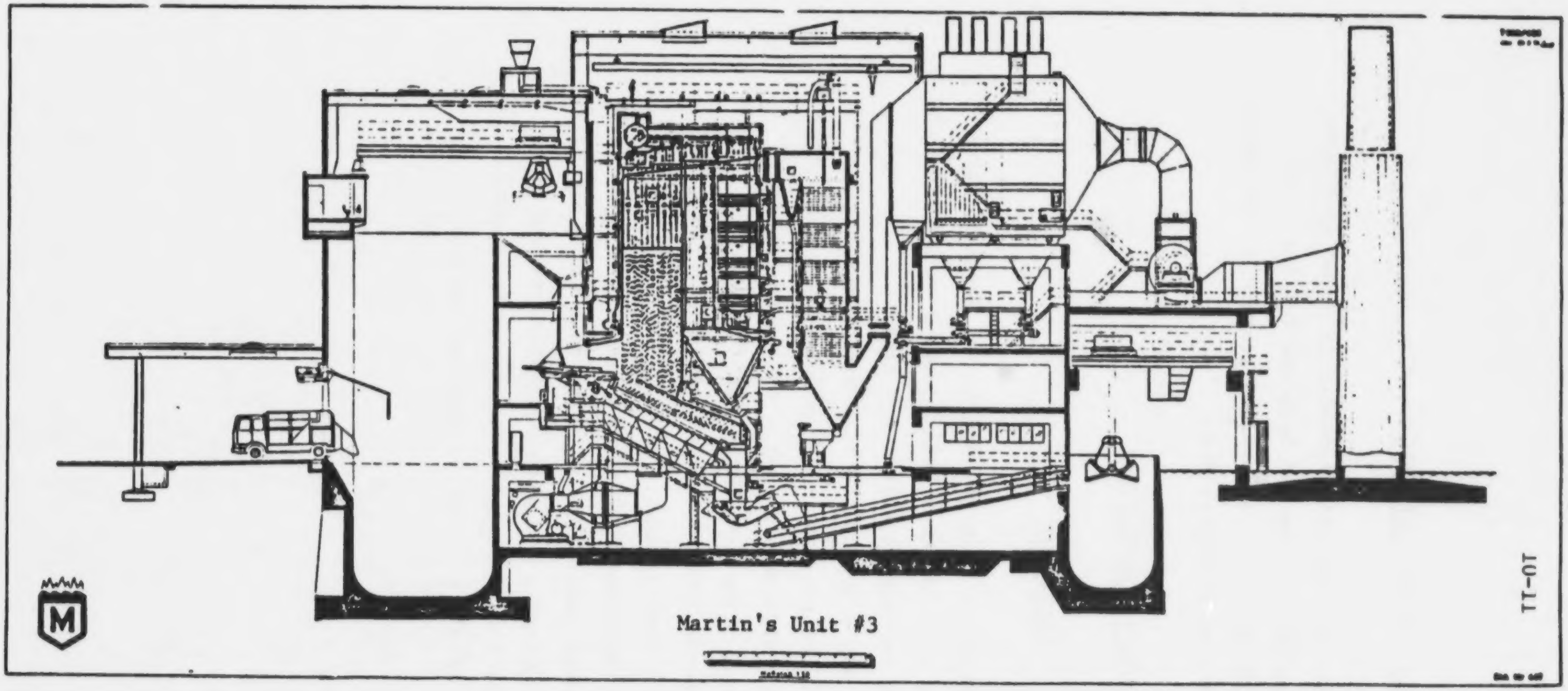
COMMUNITY DESCRIPTION

Geography

The Zurich metropolitan area is located in the Northern foothills of the Swiss Alps. The land is thus gently rolling except near the suburb of Hagenholz where the terrain is relatively flat.

The City of Zurich has a population of 388,000 people. The Hagenholz plant serves 560,000 people, not only in Zurich but also other neighboring suburbs. The population has recently decreased because Mediterranian workers went home after the "Swiss for the Swiss" referendum. The concurrent world recession has also contributed to a return to family farms and the countryside.

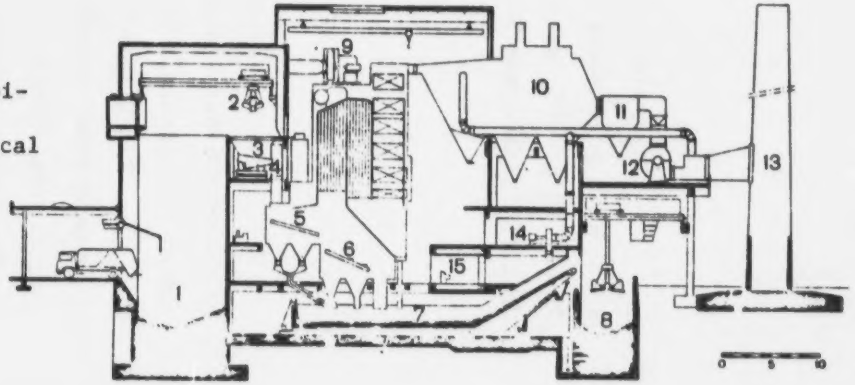
Industry and other employment activities are well diversified. There were no mentionable unique generators of waste that would affect Hagenholz plant operations. Hagenholz is much overloaded as the City refuse collection (Abfuhrwesen) increases; hence, the city is completely rebuilding the Josefstrasse facility closer to downtown Zurich.



Martin's Unit #3

FIGURE 8-1. FACILITY CROSS-SECTIONAL VIEW OF THE DESIGNS AT ZURICH: HAGENHOLZ

1. Refuse bunker
2. Crane bucket
3. Vibrating hopper
4. Chute
5. Von Roll burning grate
6. Von Roll after burning grate
7. Ash discharger
8. Ash bunker
9. Primary air fan
10. Electrostatic precipitator
11. Multicyclone mechanical collector
12. Induced draft fan
13. Stack
14. Flue gas recirc.
15. Control room



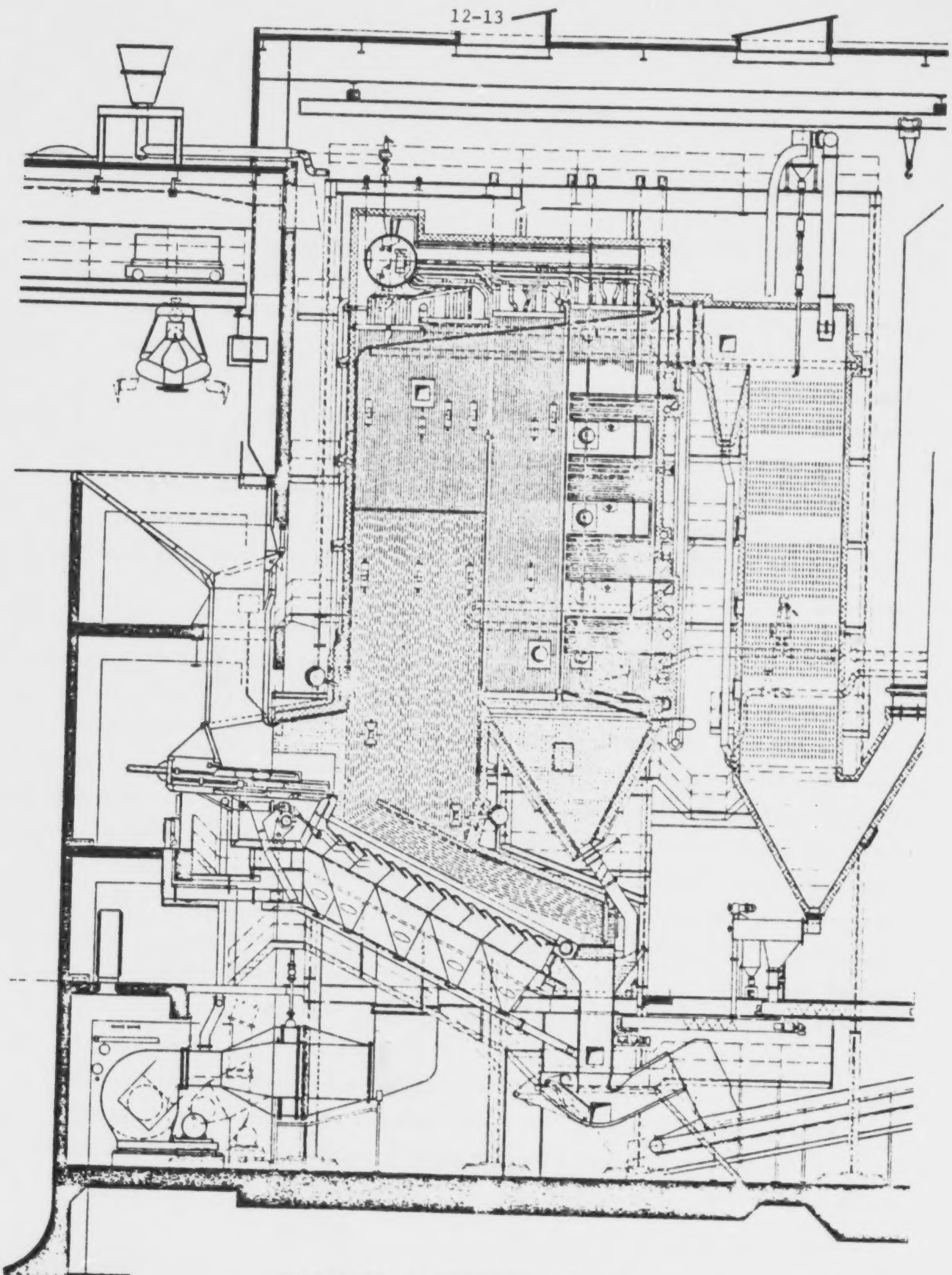


FIGURE 8-2. FURNACE/BOILER CROSS-SECTIONAL VIEW OF THE ZURICH: HAGENHOLZ UNIT #3

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SOLID WASTE PRACTICES

Solid Waste Generation

Not all waste generated in the Zurich area was collected under Abfuhrwesen control until recent years. Figure 8-3 portrays the recorded history of collection from 1905 until the present. The 400 percent increase from 1969 to 1974 reflects the scope of record keeping more than it reflects true generation and collection of solid waste. The weekly pattern of refuse treatment is shown in Figure 8-4.

Sources of waste during 1976 are shown in Table 8-1. Note the importance of non-Abfuhrwesen collection and the receipt of waste oils, solvents, and chemicals. The waste oils are burned. The chemicals, however, are collected and transferred to an industrial and hazardous waste treatment center.

The city provided several tables describing solid waste composition. Table 8-2 shows physical component percentages for studies that have been made in Switzerland, the U.S.A. and the U.K. The first Swiss column is what was used in planning Hagenholz Martin Unit #3. Calorific values are shown in Table 8-3 for common components in waste.* A 1969 study by EWAG (a testing service) and Von Roll showed values between 1950 and 2150 kcal/kg (3510 to 3870 Btu/pound). Since 1965, the lower heating value has risen only modestly. Plastic percentages are not rising very fast. Unit #3 was designed for calorific values ranging from 1600 to 3300 kcal/kg (2880 to 5940 Btu/pound). Presently, the calorific value with 20 to 25 percent moisture ranges from 2200 to 2400 kcal/kg (3960 to 4320 Btu/pound). Elemental percentages for Swiss municipal solid waste are shown in Table 8-4.

At Hagenholz, slightly over 800 tonnes (880 tons) per day of solid waste are received on a five day collection basis. This converts to slightly over 600 tonnes (660 tons) per day on a seven day burning basis. The plant gates are open Saturday mornings to receive trash from private vehicles.

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*Every reference to refuse calorific value relates to the lower heating value commonly used in Europe (and not the higher heating value used in the U.S.A).

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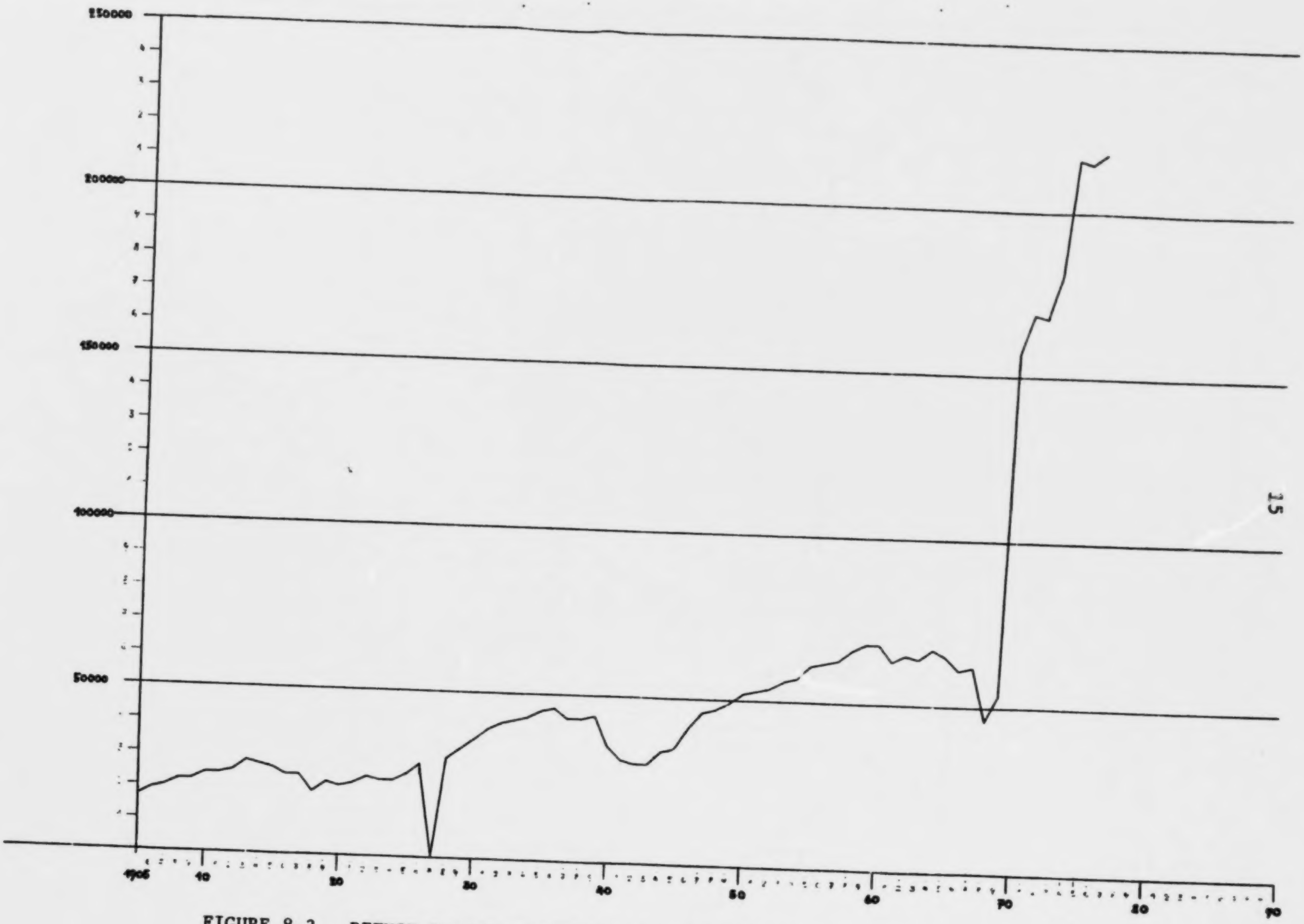


FIGURE 8-3. REFUSE BURNED AT THE ZURICH JOSEFSTRASSE AND HAGENHOLZ PLANTS FROM 1905 TO 1976, TONNES PER YEAR

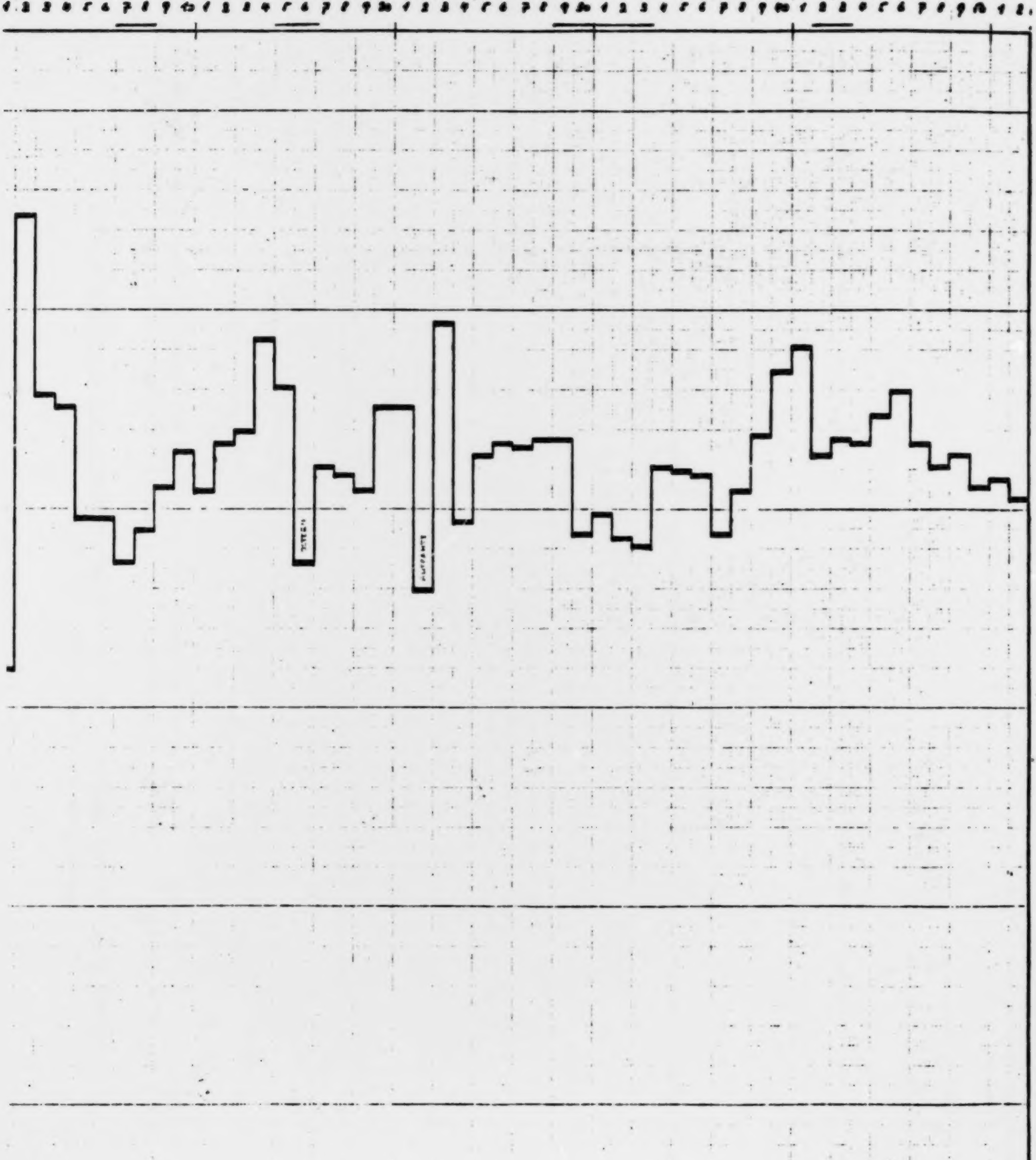


FIGURE 8-4. 1976 WEEKLY REFUSE COLLECTIONS IN ZURICH

TABLE 8-1. SOLID WASTE DELIVERED TO
ZURICH: HAGENHOLZ
IN 1976 (VOLUME AND WEIGHT)

	1976			
	Volume (m^3)		Weight (tonnes)	
In bags and containers (specific weight; 140 kg/m^3)	818,000		114,470	
Commercial/Industrial wastes (hotels, offices, etc.)	1,129		852	
Bulky wastes	26,767		6,237	
Total collected by Abfuhrwesen		845,896		121,559
From privates (175 kg/m^3)	222,000		38,850	
From other community (175 kg/m^3)	316,500		55,390	
Total not collected by Abfuhrwesen		538,500		94,240
From garages			768	
From privates			1,015	
Total waste oil				1,783
Other waste (solvents, chemicals, etc.)				6,013
GRAND TOTAL				223,595

Source: Stadt Zurich Geschaftsbericht 1976
Gesundheits - und Wirtschaftsamt
pages 32 and 33

TABLE 8- 2. COMPOSITION OF MUNICIPAL SOLID WASTE IN SWITZERLAND, U.S.A., AND BRITAIN

Constituents	Composition by Weight Percent (%) (Location and Source)						
	Switzerland			U.S.A.		Britain	
	1	2	3	1	4	5	6
Food waste	20	12	14.5	6	14	26	13
Textiles	4	2.5	3.0	3	-	2	2.5
Paper	36	30	33.5	40	55	37	51.5
Plastics	4	7	2	4	1	1.5	1.0
Leather and rubber	2	-	-	2	-	-	-
Wood	4	6	2.5	2	4	-	-
Glass	8	5	8.5	17	9	8	6.5
Ferrous and nonferrous metals	6	7	5	9	9	8.5	6.5
Street sweepings and garden waste	6	-	-	5	5	2	3
Stones, dust, and other debris	10	33.5	31	12	3	15	16

Sources:
1. National averages as published by EAWAG (1971) (used for planning Hagenholz)
2. Municipal solid waste of Geneva (1972)
3. Municipal solid waste of Zurich (1963/1964)
4. USA (1970 - 72)
5. London (1972)
6. Birmingham (1972)

TABLE 8-3 . ENERGY VALUES OF SELECTED WASTE TYPES (DRY)

	kcal/kg
Average waste	1600 - 3400
Constituents (in relation to the dried products)	
paper	4160 - 4460
plastic, leather, rubber	5600 - 6450
food waste	4775
textiles	4500
wood	4820
Forest and wood industry residues	4090
Agriculture and food industry waste	2780
Tires	8230
Bituminous coal	5600 - 8100
Gasoline	11400
Methanol	5420

Source: Various sources.

TABLE 8-4 . AVERAGE CHEMICAL COMPOSITION
OF MUNICIPAL SOLID WASTE
IN SWITZERLAND

Constituent	Composition in weight %*
Water	32.90
Material containing organics	
Decomposable material	36.20
Carbon	20.20
Hydrogen	2.60
Chlorine	0.34
Nitrogen	0.57
Phosphorus	0.12
Organic material total	41.00
Material containing minerals	
Carbonate	0.86
Potassium	0.11
Calcium	2.40
Sodium	0.54
Magnesium	0.24
Ferrous	2.35
Mineral material total	26.10

*The table is not composed for totals to be summed.

Solid Waste Collection

Solid waste collection is performed by the City of Zurich, Department of Streets and Sanitation, (Abfuhrwesen) by private collectors and by other communities. The 130 Abfuhrwesen vehicles typically make four trips per day carrying about five tonnes per truck per day.

Beginning in 1970, Abfuhrwesen began using plastic and paper sacks in place of metal containers. This has had a very positive effect on reducing collection personnel and hence costs as seen in the later Figure 8-35.

The previous Table 8-1 infers more information about collection activities. Considering only the solid waste, the collection activities are performed in 1976 by the three types of collectors in the following manner:

Abfuhrwesen (City of Zurich)	56
Other municipalities	18
Private haulers and businesses	26
	100% by weight

Solid Waste Transfer Activity

The Hagenholz facility is used as a location for anyone to dispose of properly containerized hazardous (non-radioactive) wastes and industrial chemical waste. In Europe, as compared to the U.S.A., there is a much greater emphasis on municipal responsibility for treatment and disposal of such wastes.

Private haulers simply bring their containers to a rear area of the plant for temporary storage. When enough waste of a certain category is stored, then a truck load of material is taken to the relevant treatment center. Presumably, some of the material is taken to the privately operated hazardous waste processing plant adjacent to the Baden-Brugg refuse fired steam generator (RFSG) that was discussed in a separate trip report.

Source Separation Programs

The community has just started three voluntary recycling centers for glass, cans, and waste paper.

Abfuhrwesen has had seven centers for collection of used crank case oil. Garages and private individuals bring their waste oil to the centers. However, no money changes hands.

DEVELOPMENT OF THE SYSTEM

Background

Zurich began its long history of converting waste into energy back in 1904 at the unit pictured in Figure 8-5 on Josefstrasse. In fact, efforts are now proceeding to develop a 75-year anniversary brochure that will be released in 1979.

Operations continued until 1927 when the plant was temporarily closed for rebuilding. The plant reopened in 1928. Refuse consumption rose from 30,000 tonnes (33,000 tons) per year to 70,000 tonnes (77,000 tons) per year in 1959. Between 1959 and 1968, the overloading results became pronounced as corrosion repairs increased. During the period, extra waste had to be landfilled on farm land. By 1969, tonnage consumption had dropped to 50,000 tonnes (55,000 tons).

By 1965 a long range plan had been developed where two large RFSG units would be built, one on each side of the Limmat River (the river flowing through the old city's centrum). Because Josefstrasse was south of the river, officials decided to build a 520 tonne (572 ton) per day facility at Hagenholz, a northern suburb. This was one of the few remaining open industrial spaces in the city.

Partially because of Von Roll's local presence and because of their excellent reputation throughout Europe, Von Roll was chosen to build two 260-tonne (286 ton) per day units with room set aside for a third unit later on. The construction begun in 1966 was completed in 1969. Waste consumption immediately jumped to about 170,000 tonnes (187,000 tons) per year at both plants.

NOTE: These first two furnace/boilers at Hagenholz have experienced considerable problems. Battelle decided to visit Hagenholz, not because of these first two units but because of the later added excellent Martin unit that has experienced almost no corrosion. Nevertheless, the general history of the first two units needs to be

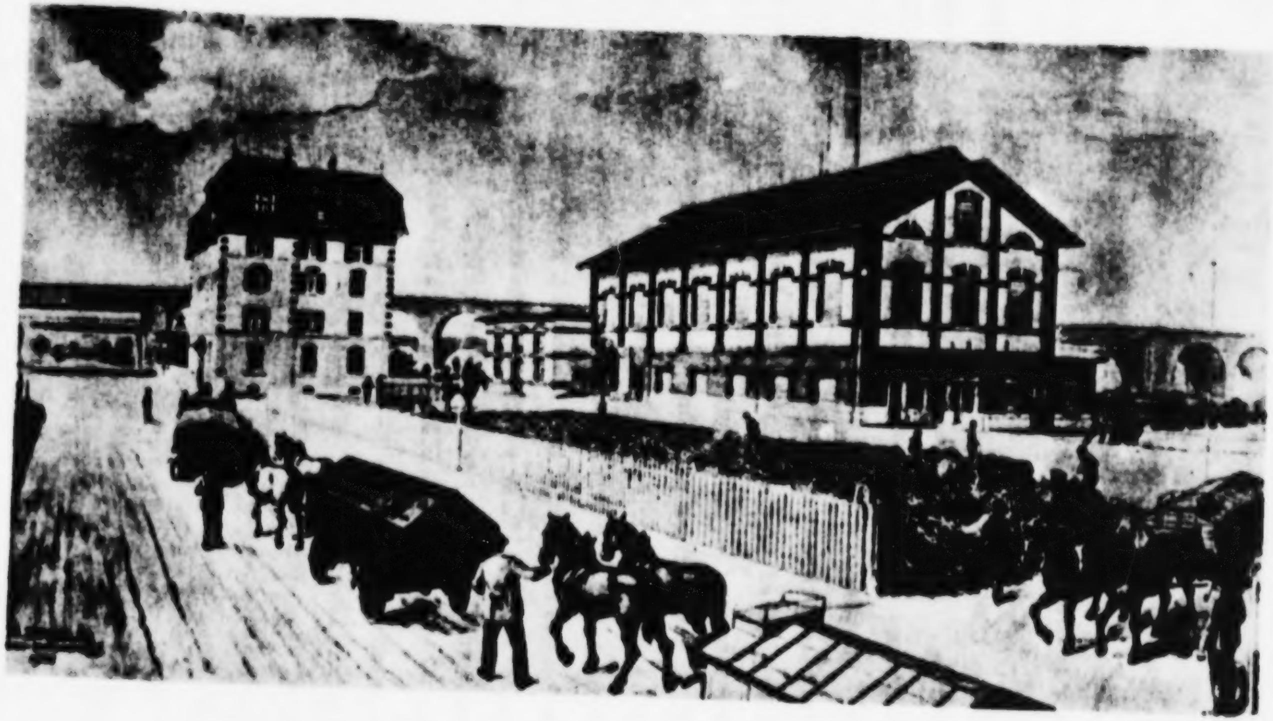


FIGURE 8- 5. ARTIST SKETCH OF THE 1904 REFUSE FIRED STEAM AND ELECTRICITY GENERATOR AS MANUFACTURED BY HORSFALL-DESTRUCTOR CO. AT ITS LOCATION ON JOSEFSTRASSE IN ZURICH.

explained because of its philosophical impact on the design of the third unit and because of a most important lesson to be learned.

This report has been carefully reviewed by both Von Roll, Martin, and their American representatives.

The basic problem with the first two units is that the refuse calorific value rose much more than expected. The 1945 values of 1000 kcal/kg (1800 Btu/pound) were known to have risen, but how much was apparently unknown. Likely, no one in the City Administration nor at Von Roll expected the 1969 value to be 1950 to 2150 kcal/kg (3510 to 3870 Btu/pound) as was later measured by Von Roll and EWAG, the Government's testing service. Thus, the plant (well designed for rather low calorific value waste) had to burn waste that was 50% to 100% hotter.

The gas flow passages between the boiler tubes were properly designed to be small - assuming the "cool" waste. But the result with the "hot" waste was excessive sticking of hot, fused flyash on boiler tubes causing eventual blockage. The sticking is caused by the flyash fusion temperature being often exceeded as temperatures in the boiler convection section were around 600 C (1112 F). These sticky deposits interfered with heat transfer hence the flue gas leaving the boiler was very high. These high temperatures corroded the boiler tubes and the electrostatic precipitators.

To reduce sticking and corrosion, less waste was fed and primary and secondary air was reduced. Elsewhere, the rubbing action of the grate bars against each other had worn away grate metal so that the air spaces were larger. With the lower volume and pressure of underfire air, objects fell between the bars and down into the siftings removal system. Fires under the grate became common.

The net effect on energy delivery was negative. The city had specified 28 tonnes (31 tons) steam per hour per furnace. Unfortunately, to run the system, about 17 to 19 tonnes (19 to 21 tons) steam per hour per furnace could be produced as shown below:

	1974	1976
Furnace/Boiler #1	23.7 tonnes	18.7 tonnes
Furnace/Boiler #2	18 tonnes	17 tonnes
Original Rated Steaming Capacity	28 tonnes	28 tonnes

Moving ahead to total operating Tables 8-5 and 8-6, notice that the long overdue rebuilding of Units #1 and #2 was done in 1974. These units now operate a normal set of hours per year as also shown below when compared to the Unit #3.

	1974	1976
Furnace/Boiler #1 (Von Roll)	4,766 hours	7,463 hours
Furnace/Boiler #2 (Von Roll)	4,561 hours	7,289 hours
Furnace/Boiler #3 (Martin)	7,004 hours	7,596 hours
Total Hours in 365 day year	8,760 hours	8,760 hours

At Hagenholz most parties back in the early 1960's underestimated "the heating value in 1965 and grossly underestimated the value for the 1970's." As a result, the system (1) was grossly overheated, (2) had been designed for low furnace wall tube surface area for heat removal prior to the superheater, (3) had small boiler passes designed, (4) suffered with slagging on furnace walls and tubes, (5) developed corrosion on boiler tubes, (6) developed high temperature corrosion in the electrostatic precipitator, (7) suffered reduced air pressure under the grate, (8) increased number of fires in the siftings hoppers, (9) reduced production of steam, etc.

This report mentions at several places management's emphasis is on energy production. This has been contributory to some of the Unit #1 and #2 problems. The original contract specified operation at the "continuous maximum load." The term was never clearly defined as to whether this meant "peak" or "average" or "maximum average load over the long running time."

Plant officials interpreted the rated 28 tonnes of steam per hour to be the maximum average load over the long-running time. Von Roll had, however, designed the plant assuming that the 28 tonnes of steam would be permissible for short periods as a holdable peak--but not for continuous operation.

Going back to the energy emphasis, plant staff began a campaign to increase the volume of high calorific value industrial waste. The vendor, of course, claimed that (to paraphrase) "It's not fair to ask Von Roll to build a unit for 1200-1500 Kcal/kg refuse and then purposely try to load it with high calorific value refuse at 2200 to 2400 Kcal/kg. Of course it will have problems."

The experience at Hagenholz and other similar experiences in Europe have sensitized system designers to push for an accurate current estimate of calorific values. More searching for accurate forecasts of calorific values is needed as well.

The concern about Hagenholz Units #1 and #2 resulted in the design of a later unit at Hamburg: Borsigstrasse to be over-compensated. So much heat was extracted by the boiler that plant operators would worry about keeping the refuse properly burning. The writers now believe that all parties involved have carefully studied the parameters and that such problems will not recur at future installations--if designers and system purchasers will respect the calorific value of waste.

The Hagenholz full story will not be described in this report. Contracts, guarantees, politics, personalities, etc., could be the subject of a book and are not that relevant to this report. The item that is relevant is:

LEARN THE PRESENT COMPOSITION OF WASTE AND ESTIMATE FUTURE TRENDS.

Beginning of Subject System

The technical problems experienced on Units #1 and #2 and the inability of the City and Von Roll to agree and then resolve the problems led to a prejudiced view of the firm for Unit #3. By 1970, other firms had improved their technologies and reputations.

Martin assigned one of its top project managers, Heinz Kauffmann, to work with the City. Max Baltensperger opened his pre-bid discussions to all vendors. Apparently, Martin seized the opportunity with more vigor and apparent thoroughness.

Erich Moser explained the City's philosophy that "this plant is not at a price but rather the City asked what can we build that will be most reliable." Another comment was, "The biggest (most important) thing is the grate."

Another philosophical comment, "Some people spend so much (money) on architecture . . . and then skimp on the (furnace/boiler) equipment. (Another plant) has a very nice entrance but can't make money."

They wanted "maximum reliability with mimimum maintenance, a 4000 hour guarantee, a minimum of 1-1/2 m^3 waste water hour, particulate emissions under 75 mg/Nm^3," etc.

Three bids were received: Martin, Von Roll, and VKW. The VKW chute-to-stack bid of SF 9,000,000 was lower than the SF 11,430,000 bid of Martin. Yet Martin was chosen due to the City's confidence in Martin's ability to produce an excellent system.

Building the Subject System

The result of this unusual attention to design details is a unit that is one of the finest in Europe. Construction was finished in early Fall of 1973. There were no appreciable construction delays. The bid was fixed price and there were no appreciable financing problems.

Next System Under Construction (Josefstrasse)

Once the Martin Unit #3 had successfully passed its 4000 hour compliance test in 1973, the City began discussions about replacing the second generation (1927-1976) Josefstrasse plant with a third generation (1979) Martin plant. This plant is now (1977) under construction at the original site.

PLANT ARCHITECTURE AND AESTHETICS

Plant Design

The plant is located on the "last available site of sufficient size" considering the City of Zurich and the suburb of Hagenholz. It seemed to be near the far end of an industrial park. As a result, trucks must drive back on an industrial road that sometimes becomes overloaded with traffic.

Being in a secluded portion of an industrial park, the landscaping is appropriately modest. This is also consistent with managements' continued emphasis of putting money into the furnace/boiler and not into pleasantries and "frills."

The plant design (see Figure 8-6) might be characterized as blocky concrete. Very few windows were allowed, thus reducing noise. Regarding noise limitations, the plant seems to be meeting the 45 decibel rating for 100 meters.

The entire front wall of the control room faces the discharge portion of the furnace.

The basic building is 26 meters (85 feet) high. The 91 meter (300 feet) tall stack is built on a platform several meters from the building.

The plant operates under negative pressure so any odors generated in the pit are collected in the primary air system for combustion in the furnace.

Rendering Plant Gases (see also Secondary Air section)

The most noteworthy, aesthetic feature of the Zurich-Hagenholz plant is its consumption of rendering plant gases. Max Baltensperger is responsible not only for recovering energy from municipal waste but also for manufacturing flesh-meal and industrial oils and fats from animal carcasses. In the careful design of the new rendering plant, room air collection vents and process vents are placed to suck, under negative pressure, all of the gases into a common pipe. This horizontal pipe is extended from the rendering plant (see Figure 8-7) to the refuse fired steam generator for use as secondary air. As a result, virtually all unpleasant gases associated with the normal rendering plant never enter the environment.

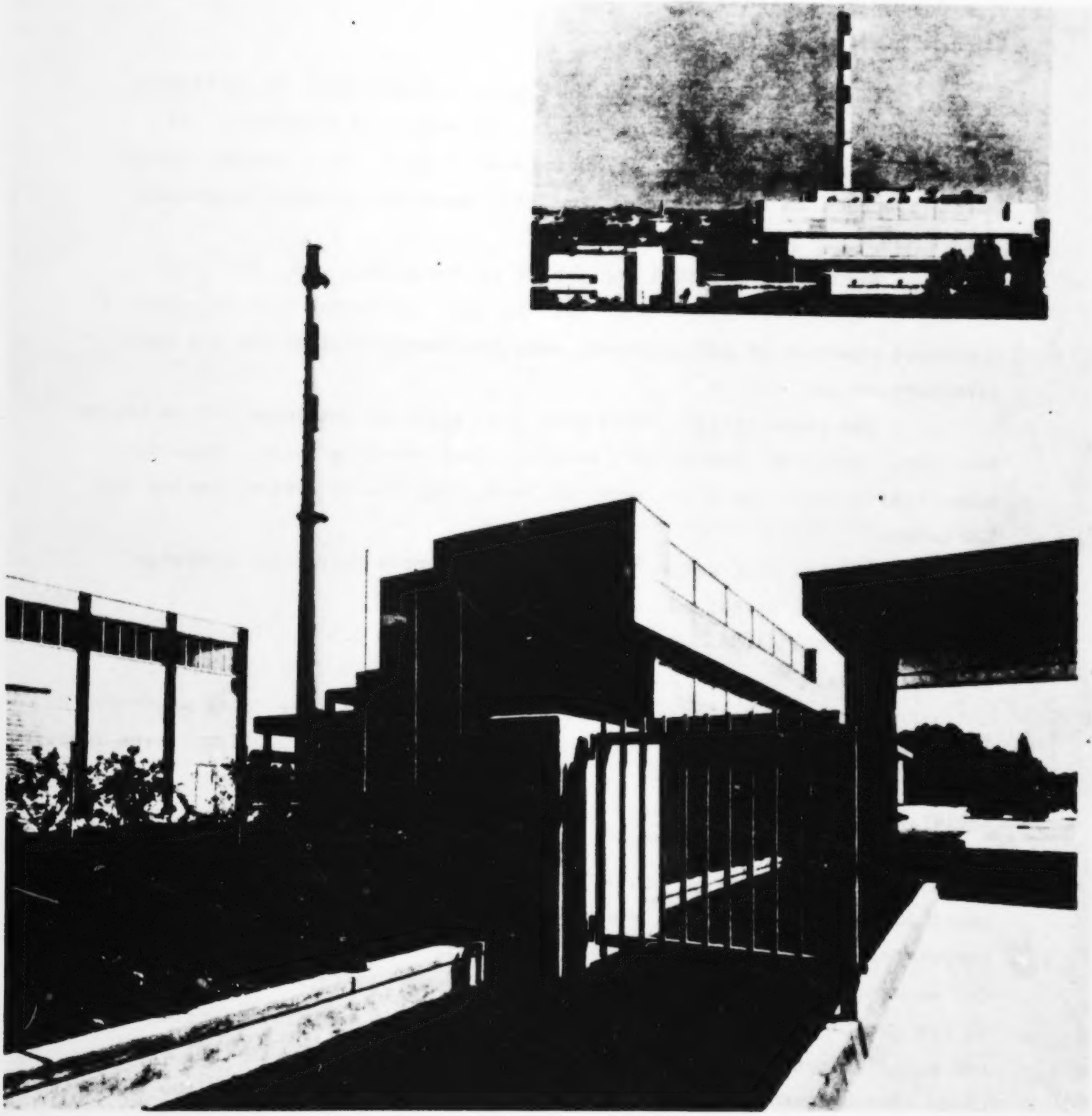
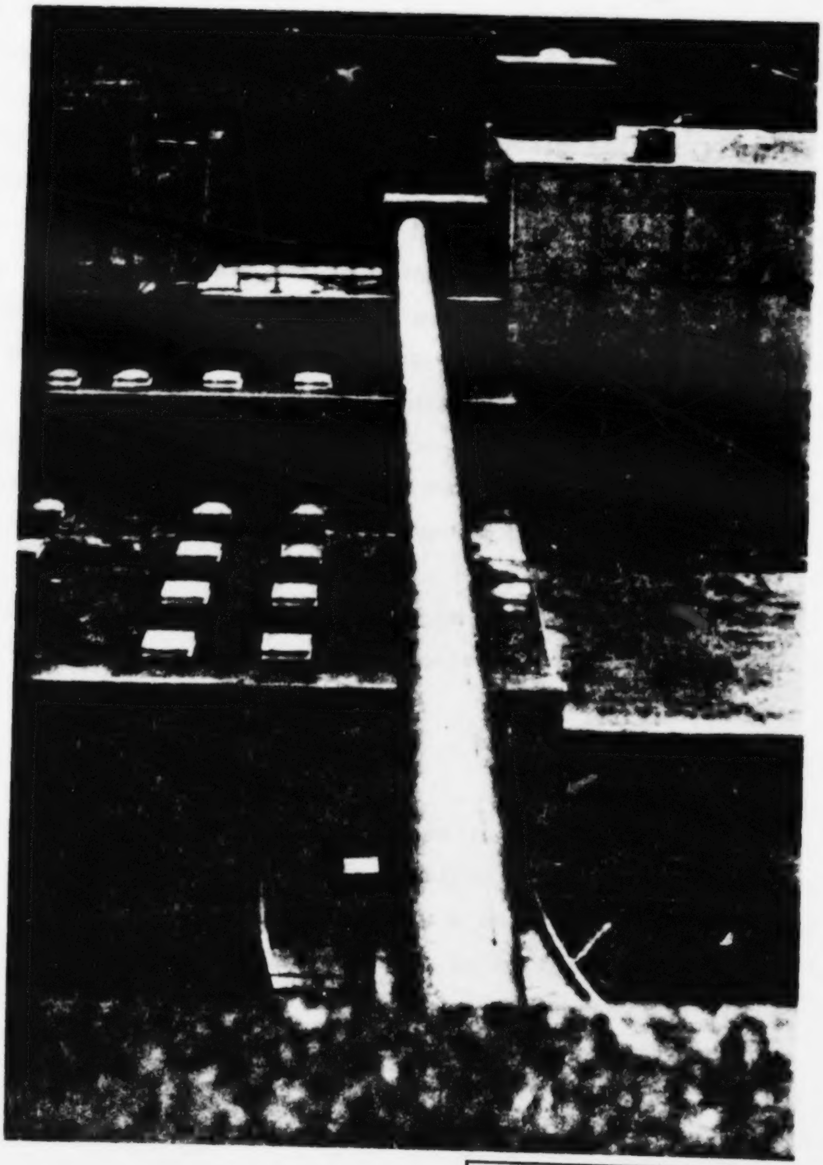


FIGURE 8-6 . VIEWS OF THE ZURICH: HAGENHOLZ
REFUSE FIRED STEAM GENERATOR
(Courtesy City of Zurich)



Reproduced from best available copy.

FIGURE 8-7. HORIZONTAL VENTILATION AIR PIPE FROM RENDERING PLANT TO ZURICH: HAGENHOLZ PLANT (Battelle Photograph)

For years, the U.S. EPA has investigated means of controlling these organic gases. Absolute control would entail expensive use of natural gas afterburners. A former president of the National Renderers Association now working at the Columbus, Ohio, Inland Products plant has been retrofitting his plant with suction equipment around selected processes. The gas is then injected to the plant's oil fired boiler as combustion air. This procedure could be most important and relevant to the U.S. EPA's philosophy of non-degradation of the atmosphere. During 1977, the U.S. Congress has been discussing an environmental control philosophy that would permit construction of a new source generating a given pollutant if an old source is either better controlled or closed.

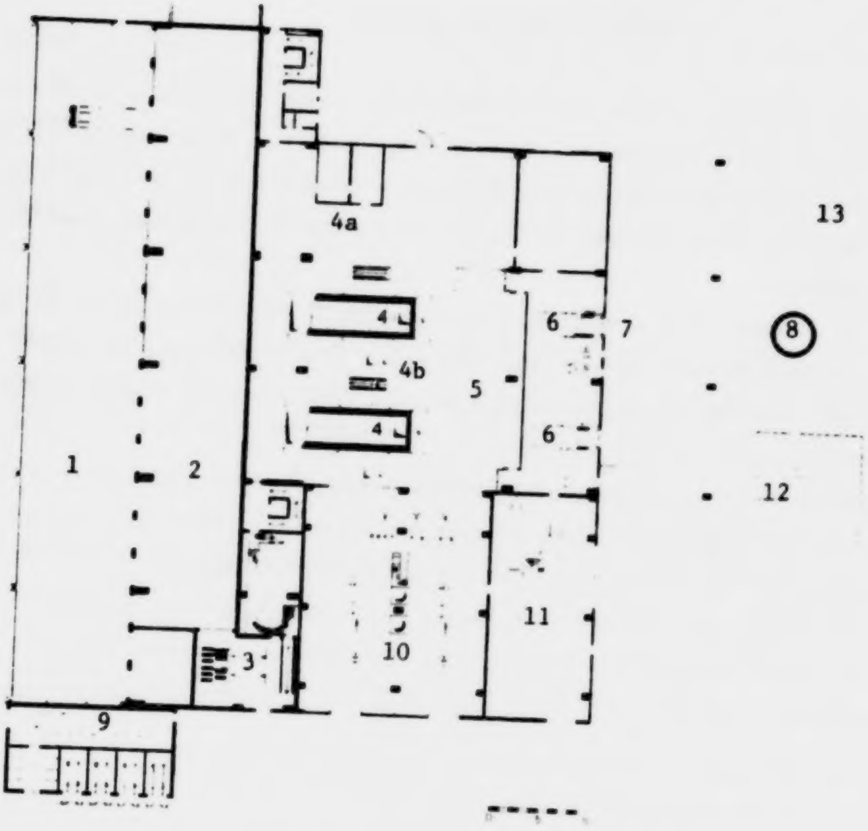
The Hagenholz example is not quite the same thing. There, the combination of plants may have minor air particulate emissions from the RFSG stack, but has eliminated non-particulate odors from the old rendering plant.

For the complete story on rendering gases the reader should read the later appearing section on secondary air.

Comment

Battelle believes that the spirit (but not the precise words) of the Congressional discussions could be served in a community now having an odoriferous rendering plant and a municipal solid waste disposal problem. We would suggest consideration of a Sanitary Park with at least two occupants: (1) the rendering plant and (2) the refuse fired steam generator.

We are also wondering whether the components of various reduced sulfur rendering gases could be contributing to elimination of the tube corrosion threat. This has been suggested by corrosion researchers at Battelle and is being investigated at a U.S. plant.



1. Tipping Floor
2. Refuse Bunker
3. Bulky Waste Shear
4a Furnace/Boiler (Martin)
4b Furnace/Boiler (Von Roll)
5. Control Room
6. Ash Discharger
7. Ash Bunker
8. Chimney
9. Storage
10. Turbogenerators
11. Fuel Oil Boiler
12. Waste Oil Processing Plant
13. Solvent Receiving Station

FIGURE 8-8. OVERHEAD VIEW OF ZURICH: HAGENHOLZ

TOTAL OPERATING SYSTEM

Any visitor to the Zurich-Hagenholz plant will soon be discussing the Von Roll #1 and #2 units and the Martin #3 unit. This report is intended to fully discuss the Martin #3 unit. Nevertheless, we feel that certain operating data for all three units should be presented, but in proper perspective.

To repeat from a previous section, most of the problems of units #1 and #2 derived from a design for "somewhat over 1000 kcal/kg (1800 Btu/pound) waste" instead of waste actually over 2000 kcal/kg (3600 Btu/pound) as has been the case in the 1970's.

Table 8-5 presents some operating figures for 1974 which reflect poorly on units #1 and #2. But, as mentioned before, 1974 was the year for major overhauling that could not be accomplished before.

By 1976, all three units were operating on a more normal schedule as shown in Table 8-6 . Figures are also presented for the entire Sanitary Park complex including these buildings and energy customers.

- Car and truck repair shop (1,000,000 SF ($400,000) worth of spare parts in basement)
- Office building
- Workers social hall and cleanup area
- Truck garage for storage
- Rendering plant
- FBW
- City's district heating network
- Electric utility's district heating network

The units are shut down for about eight hours every 1000 hours for routine inspection and minor maintenance. Every 4000 hours or twice a year, the unit is down for about one week or two for boiler cleaning and major overhaul if needed.

During 1976, the Martin #3 unit was shut down seven (7) times for less than one day for planned 1000 hour routine inspections. In total, the unit was out of service for six (6) weeks.

Zurich used to have an instrument service contract but that became too expensive. Their own staff now repair the instruments.

TABLE 8-5 . COMPARISON OF ZURICH-HAGENHOLZ INCINERATOR PERFORMANCE, 1974

Incinerator boiler #	#1	#2	#3
Make of incinerator	Von Roll	Von Roll	Martin
Maximum throughput of solid waste Sh.T/D	286.52	286.52	521.0
Maximum Burning Rate Sh.T/Hr	11.93	11.93	21.7
Average Burning Rate Sh.T/Hr	9.18	9.18	15.7
Average Performance Rate %	76.90	60.70	72.5
Total Operating Hours Hr/Yr.	4,766.00	4,561.00	7,004.0
Availability %	54.40	52.10	80.0
Average Steam Output Sh.T/Hr	23.675	18.672	40.5
Rated Steaming Capacity Sh.T/Hr	28.00	28.00	42.1
Average Steam Output Rate %	48.60	66.70	96.4

Source: Information obtained from data given by Mr. Max Baltensperger, Director, Department of Streets and Sanitation, City of Zurich.

TABLE 8-6. REPORT OF OPERATIONS 1974 AND 1976

Annual Totals

	1974	1976
Incinerator boiler #1 operating hours (h)	4,766	7,463
Incinerator boiler #2 operating hours (h)	4,561	7,289
Incinerator boiler #3 operating hours (h)	7,004	7,596
Number 2 fuel oil fired 3-pass boiler #1 operating hours (h)	201	182
Waste oil fired 3-pass boiler #2 operating hours (h)	1,486	2,099
Incinerator boiler #1 Steam Generation (tonnes)	112,891	139,930
Incinerator boiler #2 Steam Generation (tonnes)	85,118	125,306
Incinerator boiler #3 Steam Generation (tonnes)	284,255	261,515
Total steam produced from solid waste (tonnes)	482,264	526,751
Steam generation per ton of solid waste, unit #1		
unit #2		
unit #3		
average (t/t)	2.579	2.41
Fossil fuel fired 3-pass boiler #1 - steam generation (tonnes)	1,413	1,404
Fossil fuel fired 3-pass boiler #2 - steam generation (tonnes)	11,244	13,192
3-pass boiler total - steam generation (tonnes)	12,658	14,596
Total steam generation (tonnes)	494,922	541,347
Quantity of solid waste burned (tonnes)	186,968	218,342
Quantity of waste oil burned (tonnes)	794	1,102
Quantity of waste solvents burned (tonnes)	71	113
Quantity of crude oil burned (3-pass boilers) (tonnes)	109	108
Total weight burned (tonnes)	187,942	219,665
Quantity of solid waste collected (tonnes)	186,146	217,503
Quantity of waste oil collected (tonnes)	1,654	1,801
Quantity of waste solvents collected (tonnes)	71	113
Total waste collected (tonnes)	187,871	219,417

Make-up for feedwater treatment (Gals.)	6,961,926	6,798,528
Steam turbine #1 operating hours (h)	6,090	6,565
Steam turbine #2 operating hours (h)	5,351	6,160
Steam turbine #1 electric power generated KWH	18,677,670	22,376,817
Steam turbine #2 electric power generated KWH	16,155,350	20,626,620
Total electric current generated KWH	34,697,540	43,003,437
Electric current used for incineration plant KWH	11,540,878	14,276,322
Car and truck repair shop KWH	45,373	47,791
Office building KWH	148,550	131,702
Garage building KWH	39,819	27,406
Flesh-meal plant KWH	24,456	767,760
District heating system KWH	160,668	185,378
Community service KWH	12,740	
Residue processing plant KWH		30,225
Community uses KWH	6,090	
Total consumed for plant system (kWh)	11,973,563	15,466,584
Electric current fed to utility grid (kWh)	23,151,000	28,374,000
Electric current used from utility grid (kWh)	549,700	781,000
Water used for incineration plant kg	197,668,901	125,334,528
Car and truck repair shop kg	829,796	933,240
Office building kg	1,853,945	1,721,016
Garage building kg	114,386	37,488
Flesh meal plant kg	---	8,145,720
Total water consumption kg	200,772,370	136,171,992
Water consumed per ton of solid waste (kg/S. T.)	1,162 * kg/Sh.T 63.3 gals/S. T.	686 37.3

*Normal Water Consumption Per ton of solid waste for Martin System = 20 Gals/Sh.T

Wet Residue* Sh. T	47,594,551	--
Note * not weighed after June 30, 1974		
Heat consumed by car and truck repair shop	1,296 x 10^6 Btu	1.090 x 10^6 Btu
Heat consumed by office building	2,772 x 10^6 Btu	2.895 x 10^6 Btu
Heat consumed by garage building	1,623 x 10^6 Btu	1.623 x 10^6 Btu
Flesh meal plant	---	26,425 x 10^6 Btu
Hot water to local factory	304 x 10^6 Btu	287 x 10^6 Btu
District heating system	---	531,742 x 10^6 Btu
City EWZ (investor-owned public utility)	489,700 x 10^6 Btu	65,687 x 10^6 Btu
Total Heat supplied by hot water and steam	495,695 x 10^6 Btu	629,749 x 10^6 Btu
Operational hours for bulky waste shear	2,931	2,809

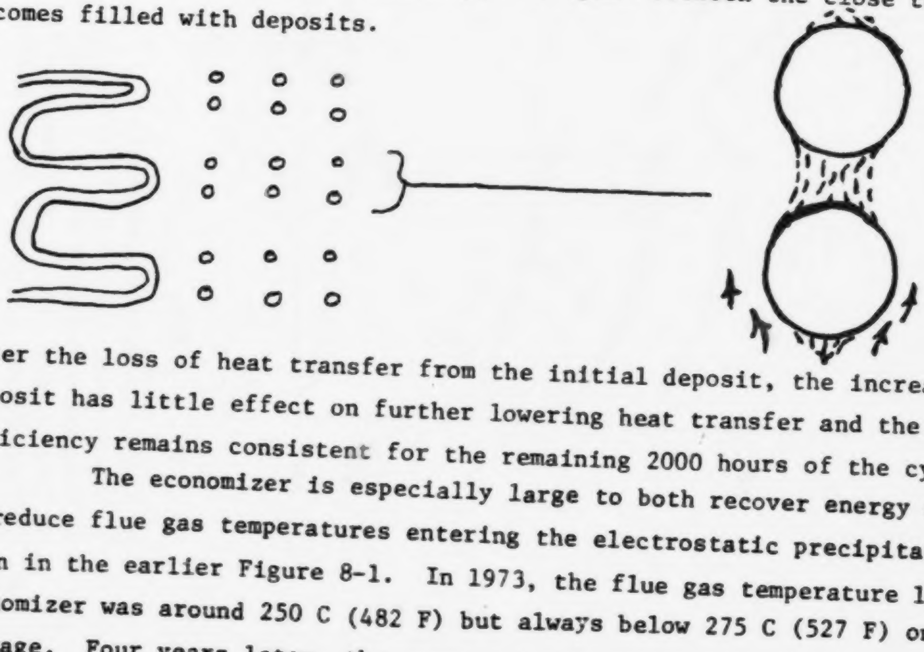
(NOTE: The causes of wide fluctuations in system energy consumption were not determined.)

The 4,000 Hour Cycle Between Boiler Cleanings. Readings of key variables on Hagenholz Unit #3 furnace/boiler have been averaged for each of 26 weeks (4,300 hours) between July 1, 1973 and February 23, 1974 (when the unit was stopped for planned cleaning) and are displayed in Figure 8- 9 .

The following Figure 8-10 is similar. It starts February 17, 1977 and goes to June when this visit was made. The unit was not stopped for cleaning. The two figures present results of the plants first half year (1973) and its latest half year of operation (1977 after 30,000 hours). For most of the 1973 period, steam production had hovered around 37.5 tonnes (41.3 tons) per hour. Four years later the figure had decreased to about 35 tonnes (38.5 tons) per hour.

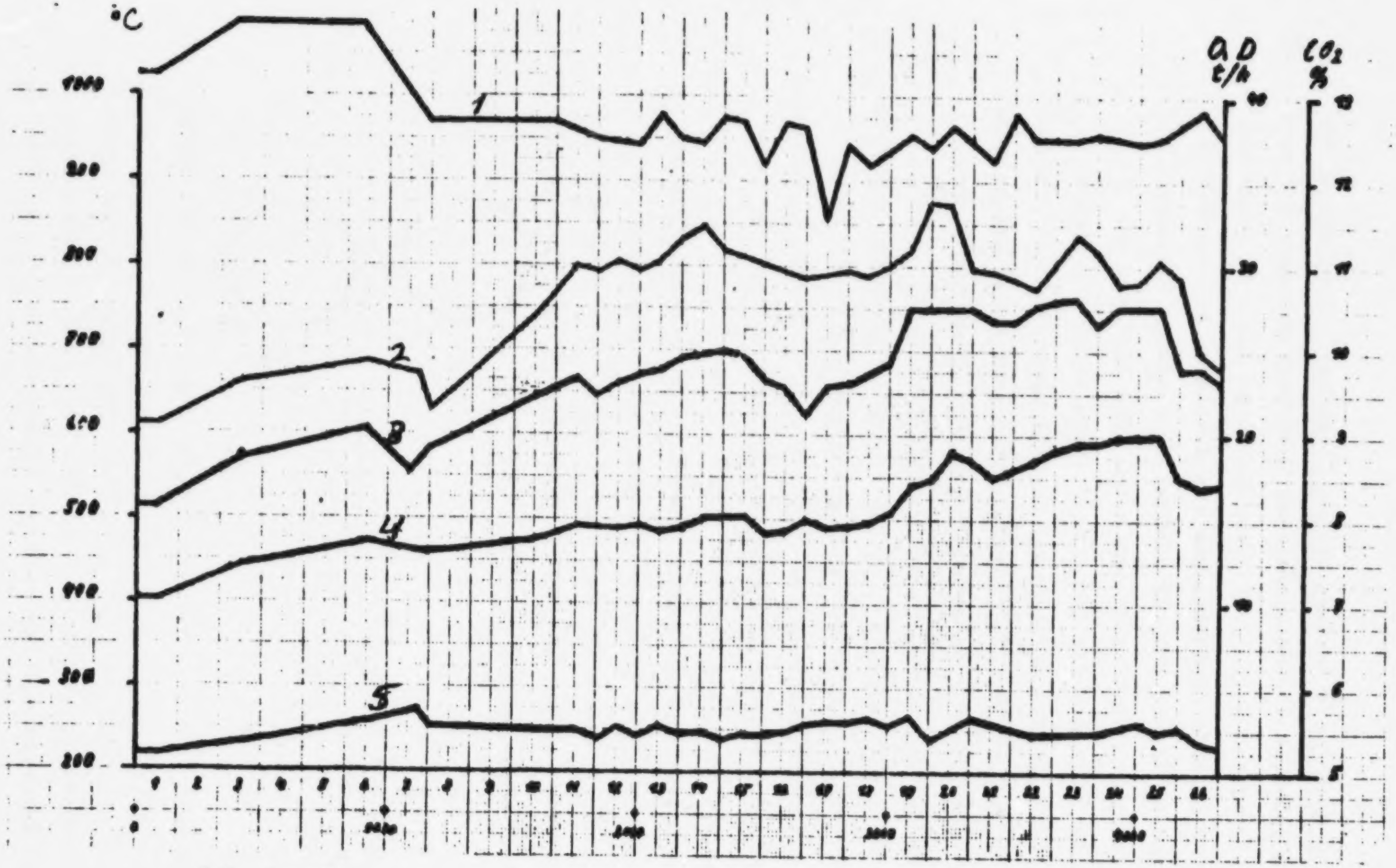
Notice the steady rise in flue gas temperatures during the first 1000 or 2000 hours. The low initial readings reflect excellent heat transfer rates due to rather clean tubes. After the tubes have accumulated deposits, the heat transfer levels out as is indicated by the flat temperature and steam profiles.

The superheater and the economizer tubes are stacked (and not staggered). During the first 1000 hours, deposits are beginning to accumulate vertically between close tubes as shown in this diagram by Martin's Heinz Kauffman. Eventually, the space between the close tubes becomes filled with deposits.



After the loss of heat transfer from the initial deposit, the increasing deposit has little effect on further lowering heat transfer and the efficiency remains consistent for the remaining 2000 hours of the cycle.

The economizer is especially large to both recover energy and to reduce flue gas temperatures entering the electrostatic precipitator as seen in the earlier Figure 8-1. In 1973, the flue gas temperature leaving the economizer was around 250 C (482 F) but always below 275 C (527 F) on a weekly average. Four years later, the average temperatures had risen to 290 C



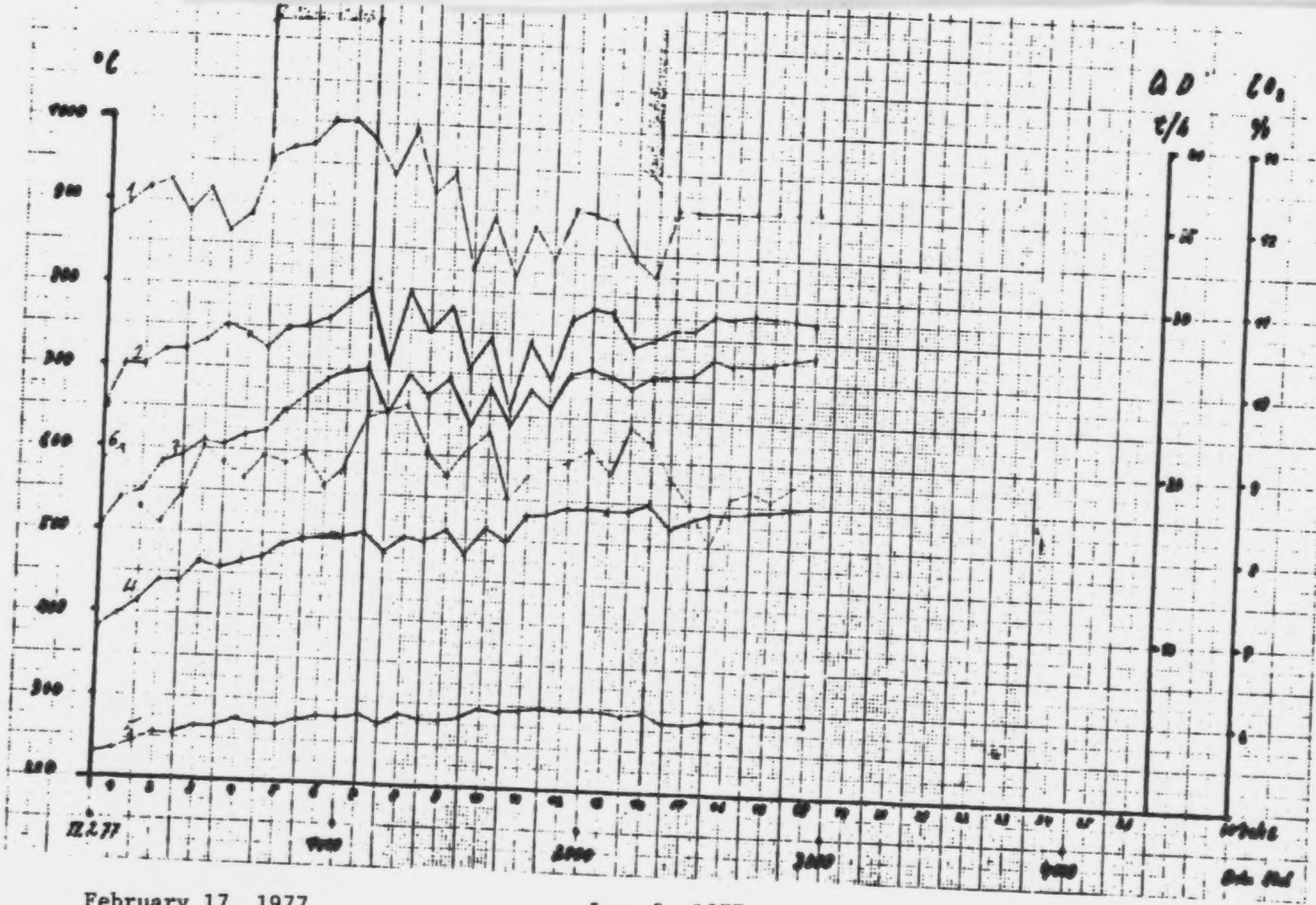
July 1, 1973

February 23, 1974

1 Steam Production (tonnes/hour)
2 Temperature at Top of Furnace First Pass (° C)
3 Temperature Before the Superheater (° C)
4 Temperature Before the Economizer (° C)
5 Temperature After the Economizer (° C)

(First Half Year of Operation)

FIGURE 8-9. STEAM PRODUCTION, FLUE GAS TEMPERATURES AND CO_2 LEVELS (WEEKLY AVERAGE) DURING THE 4000 HOUR OPERATING CYCLE BETWEEN CLEANING AT ZURICH: HAGENHOLZ UNIT #3



February 17, 1977

June ?, 1977

1 Steam Production (tonnes/hour)
2 Temperature at Top of Furnace First Pass (° C)
3 Temperature Before the Superheater (° C)
4 Temperature Before the Economizer (° C)
5 Temperature After the Economizer (° C)
6 CO_2 Concentration After the Economizer (° C)

(Last Half Year of Operation)

FIGURE 8-10. STEAM PRODUCTION, FLUE GAS TEMPERATURES, AND CO_2 LEVELS (WEEKLY AVERAGE) DURING THE 4000 HOUR OPERATING CYCLE BETWEEN CLEANING AT ZURICH: HAGENHOLZ UNIT #3

(554 F) with occasional excursions to 300 C (572 F) the temperature considered by many to be the temperature above which ESP high temperature corrosion occurs.

Should stack gas temperatures rise 90 C (162 F) above normal, then overall plant efficiency would fall by 5%, i.e., not enough energy was absorbed by the boiler tubes from the flue gas stream.

REFUSE FIRED STEAM GENERATOR EQUIPMENT

Waste Input

Normal sized refuse in garbage trucks and bulky waste is defined as pieces entering the hopper less than 1 m x 1 m x 3 m (3 ft x 3 ft x 9 ft).

The previous Tables 8-2, 8-3, and 8-4 should be referred to understand the waste composition. With a moisture percentage of 20 to 25%, the lower heating value is now 2,200 to 2,400 kcal/kg (3960 Btu to 4320 Btu/pound). The later Martin #3 unit was designed to accept waste with lower heating values from 1600 to 3300 kcal/kg (2880 Btu to 5940 Btu/pound).

Waste is received at Hagenholz five (5) days per week amounting to 4,000 to 5,000 tonnes (4,400 to 5,500 tons). i.e., 570 to 700 tonnes/day (627 to 770 tons/day) on a seven (7) day burning basis.

The Unit #3 burns 240 to 450 tonnes (264 to 495 tons) of refuse per day. Animal horns and hoofs from the adjoining rendering plant are dumped into the bunker.

Sewage sludge is not permitted as an input because the City considers its ash recovery program to be very important. Tests by R. Hirt have shown that incinerator ash, contaminated by the heavy metals in sewage sludge cause the processed incinerator ash to be less desirable as a road building material.

Weighing Operation

The scale at the plant entrance has performed very well. The scale is recalibrated once per year. Now, there are two men at the scale. Two men are assigned to direct tipping and to encourage truck drivers to clean up any spillage. Later, when the new Josefstrasse plant is operational, only one man will be at the Hagenholz scale and one on the tipping floor.

The reader may wish to review the later section on Waste Storage and Retrieval to read about why the crane scale was abandoned.

Provisions to Handle Bulky Waste

A scissor shear, manufactured by Von Roll operates from 6 a.m. to 8 p.m. five days per week. This unit operated 2,931 hours in 1974 and 2,809 hours in 1976. Normally this type of shear does not need an operator in residence because it is in motion all the time. It can process one to ten tonnes per hour.

The bulky waste shears (see Figures 8- 11a and 8-11b) operate like multiple scissors, cutting and crushing the bulky refuse between its shear beams. Seven fixed and six moveable shear beams are connected at their lower end through shaft and bearings. Each beam is equipped with double edged blades of highly wear-resistant alloy steel which can easily be turned once and reused. The moving beams are arranged in two groups of three, each group being opened and closed by a hydraulic working cylinder.

The sheared material falls through the spaces between the fixed shear beams and down into the pit. The crane operator must then carefully distribute this usually higher calorific waste over the entire pit.

The unit operates either fully or semi-automatically, with remote-control by the crane operator. Control can otherwise be exercised at the main control panel installed near the hydraulic power pac. A pre-set pressure switch at a limited pressure of approximately 120 bars is provided in the hydraulic circuit and combined with a back-up pressure relief valve, limits is reached, the forward thrust stops and the six moveable shears retract so that more refuse can fall into the V-shaped hopper. Thus, the unit is protected against damage when the shearing resistance should grow too high.

In contrast to many other size reduction methods, the Von Roll Hagenholz unit has been almost 100% reliable. Routine inspections are conducted and repairs made three (3) times per year and the expected life is at least 20 years.

The knives are completely changed every 16 months. But during that period, the edges are rotated four (4) times, i.e., once every four (4) months.

Once per week, the knives are cleaned. Bed springs and large tires can be a problem and may need to be extracted with a long hook.

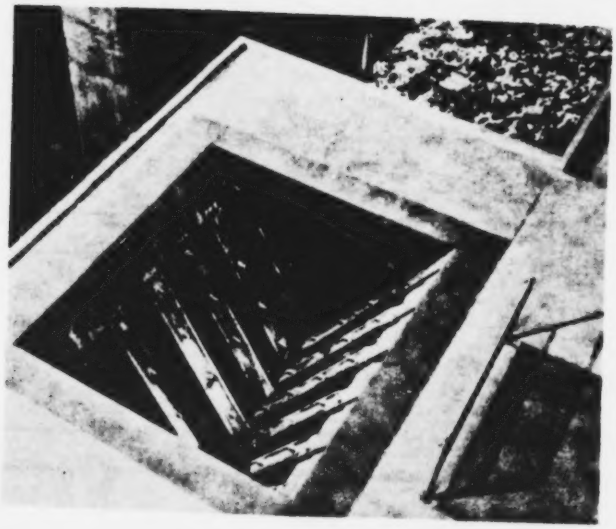


FIGURE 8-11a. VON ROLL SHEAR OPENING AT ZURICH: HAGENHOLZ (Courtesy City of Zurich)

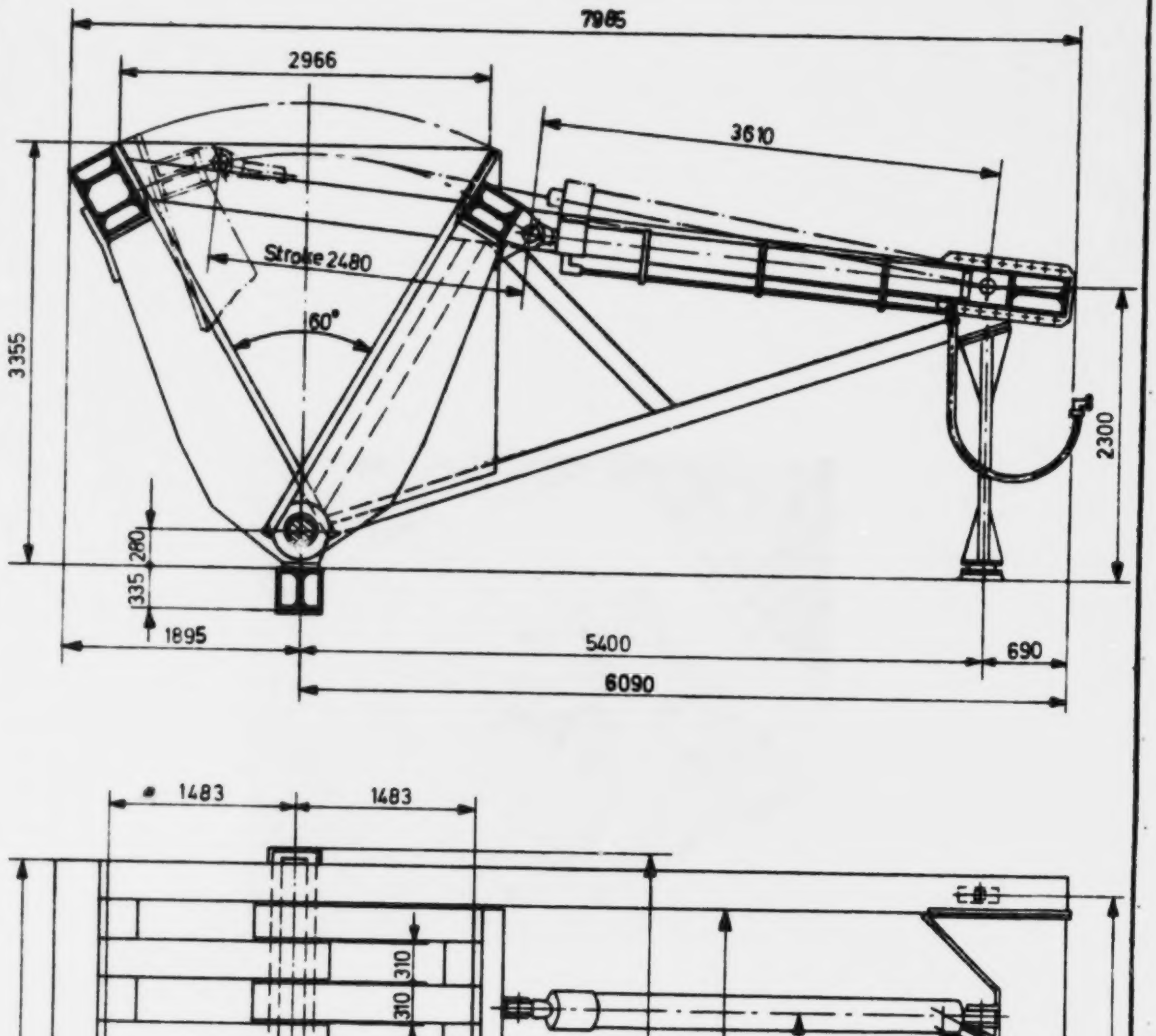

7985
2966
3610
Stroke 2480
60°
3355
2300
280
335
1895
5400
690
6090
1483
1483
310
310
4050
4245
3440
1860
3745

FIGURE 8-11b. ELEVATION AND PLAN VIEWS OF VON ROLL SHEAR

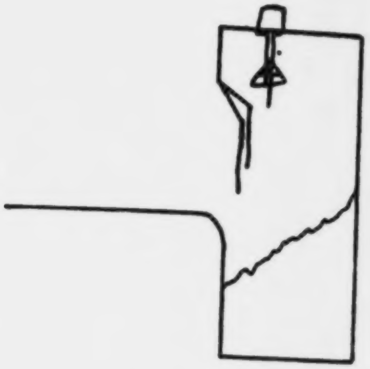
Originally, the shear was not strong enough and was later reinforced. There will be no shear at the new Josefstrasse plant because the chute will be larger, i.e. 1.5 x 6 m.

Waste Storage and Retrieval

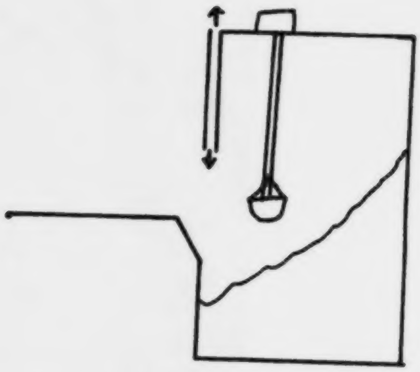
The refuse pit holds about 5,000 m^3 (6540 yds^3) or 3,000 tonnes (3,300 tons) when filled to the level of the tipping floor (see Figure 8-12). and 8-11.) When three or four doors are closed out of a total of doors, refuse can be piled up to 9,000 m^3 (11,772 yd^3). During our visit, material was so piled up that the closed doors were bowed outward.

There are fire hoses above the pit to fight small fires. Once, since 1969, they did have to call the fire department.

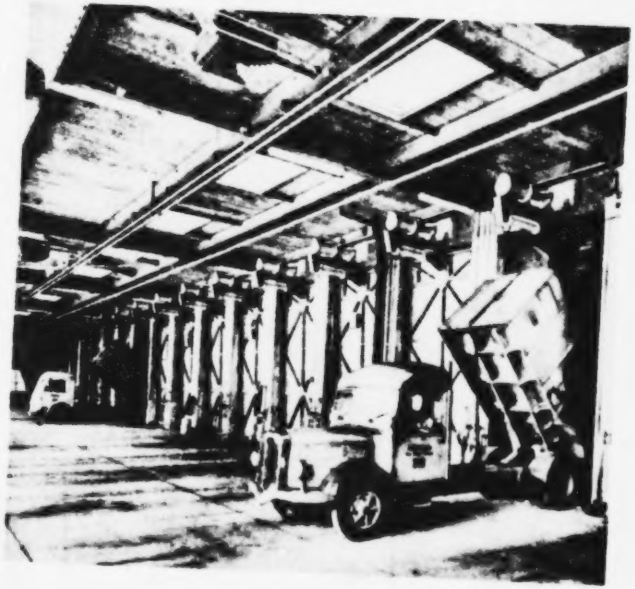
The two three-tonne (3.3 ton) cranes manufactured by Haushahn of Stuttgart are double bridge. The crane operator is in a position that is often faced with a problem of judging waste content (for calorific value and bulky items) because of the obstructed view of the opened, bended knee door that extends out into the refuse pit (see the previous Figure 8-13). As a result, the new plant at Josefstrasse will have vertically rising guillotine doors as shown below:



Existing Hagenholz



New Josefstrasse



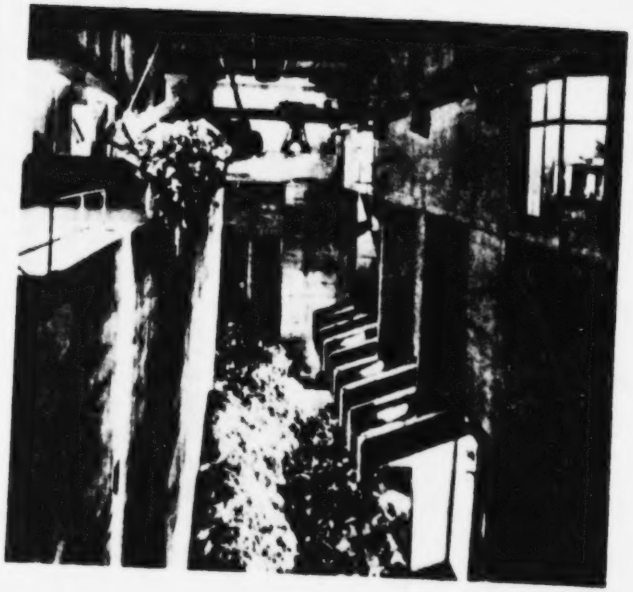


FIGURE 8-12. **TIPPING FLOOR**

FIGURE 8-13. REFUSE RECEIVING PIT
ZURICH: HAGENHOLZ
(Courtesy of City of Zurich)

Josefstrasse will have the semi-automatic crane feature that accurately places the bucket over the hopper. (The Hagenholz system is manually operated only). Hagenholz uses the less expensive clam shell buckets. However, at Josefstrasse, polyps will be used. The clam shell, while large in volume capacity does not compact well and is itself very heavy. The polyp, however, is lighter and can compact more. This results in a bigger refuse load lifted per horsepower expanded. The crane capacity at Hagenholz is 38.7 tonnes (42.6 tons) per hour while at Josefstrasse it will be 44 tonnes (48.4 tons) per hour.

The load cell on the crane failed and has intentionally not been repaired. When asked why, the response given was something like the following:

> "We don't care how much refuse we are burning. Our concern is how much steam we are producing. Hagenholz is an energy plant and not primarily a refuse disposal plant. If we repair the load cells, people may begin paying too much attention to refuse burning and not enough to energy production."

The reader is referred back to Tables 8-5 and 8-6. In no way is it possible to determine how many tons of refuse were burned per furnace in 1976.

<ins>Comment</ins>: It appears to be sophisticated to say, after everyone has been discussing energy from waste for a time, "Let's remember that these are primarily <ins>refuse disposal plants</ins> and that energy production is a secondary consideration." Plant managers at Nashville, Tennessee and at Zurich, Switzerland would likely not agree with this statement for their own systems.

We believe that the emphasis is totally a matter of local circumstances. Norfolk, Virginia has a waste disposal plant while Nashville, Tennessee has in fact an energy facility.

Some might argue with (post construction) emphasis on energy production on Units #1 and #2 with higher heat-containing waste. However, with the predeclared emphasis on energy from Unit #3, there has been no problem at all.

Furnace Hoppers

The hopper dimensions are 5.517 m (18.1 feet) by 7.056 m (23.1 feet). The hopper tapers down to the feed chute that has dimensions of 1.5 m (4.9 feet) by 5.486 m (18.0 feet). The chute is surrounded by a water jacket.

Burnback has only occurred once in four (4) years in Martin's #3 unit. While not certain, operators suspect that superheater tubes might have become plugged enough such that not all of the combustion gases could escape. Another reason might be that the I.D. fan was not functioning properly. For whatever reason, pressure likely built up and fire eventually went up the chute.

An explanation was made for the excessive burnback experience at Paris: Issy - les - Moulineaux. Issy has a very high chute. As a result, an induced draft pulls the flame back up the chute in 90% of all start-ups.

Hagenholz is thus fortunate to have a stubby chute and wide enough spaces between boiler tubes.

Feeders

Unit #3 has three (3) runs. Each run has upper and lower Martin feeders with the following specifications. Stroke frequency is a function of steam temperature, steam pressure, and temperature entering the electrostatic precipitator.

	Upper	Lower
Stroke (maximum)	600 mm	1000 mm
Stroke (normal)	180 mm	300 mm
Frequency (strokes/minute)	2 to 5	2 to 5

The feeders are hydraulically driven. As with many other components, preventive maintenance is performed on the units. The feeders are almost 100% reliable. On one occasion, a waste container of acetone spilled down the chute, leaked out of the chute and onto the rubber hydraulic lines. The acetone entering the furnace caught fire and the rubber tubes outside the chutes were destroyed. Consequently, they were replaced with steel flex hoses.

The feeders are controlled by the Martin "black box" that is extensively discussed in the Paris: Issy and the Hamburg: Stellinger Moor reports in this same series.

Zurich officials are pleased with the hopper and feeder performance and Martin will use the same design at Josefstrasse.

Primary (Underfire) Air Source and Air Preheater

Primary air is drawn from the top of the bunker, above the cranes and away from hopper discharge dust. The centrifugal forced draft fan, made by Pollrich of West Germany, produces a static air pressure after the fan of 580 mmWs. Volume maximum is 62,000 Nm^3/hour.

The primary air temperature would average around 20 C (68 F) if the GEA air preheater were not being used. With the steam air preheater on, temperatures are raised to 80 to 150 C (176 to 302 F). Hagenholz #3 (in contrast to Hamburg: Stellinger Moor or Paris: Issy, whose existing preheaters are seldom used) was properly designed for hotter waste and also hotter primary air. As a result, the preheater is almost always on and consumes 2.1 to 2.5 tonnes (2.2 to 2.8 tons) of steam per hour depending on the refuse heating value as shown below:

Lower heating value (cal/kg)	1800	1600
Exiting air temperature (C)	80	100
Refuse quantity (tonnes/hr)	15	15
Heat output (Gcal/hr)	0.985	1.160
Steam consumption (tonnes/hr)	2.120	2.500

Upon start-up, the steam used by the air preheater is not raised in the RFSG but rather it is raised in the package fuel oil boiler or from the RFSG #1 or #2. The heat produced is about 0.985 to 1.16 Gcal/hour (up to 4.7) MBtu/hr) assuming a lower heating value of 1600 + 1800 kcal/kg (2880 to 3240 Btu/pound).

Neither the fan nor the preheater have experienced maintenance problems. The fan V-belt has been changed once in 30,000 hours. The Unit #3 preheater has bare "flat" tubes through which steam passes. Units #1 and #2, instead, had "finned" tubes which caused cleaning problems. During each anticipated 4000 hour inspection, cleaning and repair activity, compressed air is used to blow off accumulated dust.

The primary air, thus preheated, passes down and into the five zone plenums under each of the three runs, i.e., 15 zones. The pressure just under the grate bars is fairly high at 50 to 150 mmWs.

The underfire air pressure is held constant. The air damper settings are rarely changed and only if the refuse is very very wet.

At the plenum hopper bottom, a siftings damper opens and closes according to an automatic timer. When open, the siftings fall and are pneumatically blown down to the bottom ash hopper.

Readings of underfire air pressure are recorded every two hours. If absolutely necessary, the pressure and flow can be changed in the control room.

Secondary (Overfire) Air

Again, Pollrich centrifugal fans are used. As discussed in the previous Plant Architecture and Aesthetics section, rendering plant gases are the exclusive source of secondary overfire air.

Of the total combustion air, roughly 80% is primary underfire air and 20% is secondary overfire air. Roughly 91 kw are required to pull a maximum of 10 Nm^3/second from the rendering plant.

There is no secondary air preheating and rendering gas temperatures average around 20 C (68 F). The maximum air volume is 16,000 Nm^3/hour.

The static pressure is 730 mmWs (mm of water). The front wall air pressure is 300 mmWs while the back wall air pressure is 540 mmWs. These very high secondary air pressures create extreme turbulence within the furnace.

Figure 8-14 shows an anonymous furnace where secondary air pressure is very low. Notice the clearly shaped flame and details of the opposite furnace wall. Turbulence is very low.

FIGURE 8-[illegible]. ANONYMOUS FURNACE WHERE SECONDARY OVERFIRE AIR IS VERY LITTLE OR TOTALLY LACKING

Figure 8-15, however, presents a red ball - a glow with no discernable shape. We suspect that any carbon monoxide (CO) formed could only exist instantaneouslv before conversion to CO_2. This turbulence virtually eliminates CO. CO, if present in appreciable amounts, is thought to contribute boiler tube corrosion in RFSG.

The unusual fact is that Zurich: Hagenholz Martin #3 superheaters have experienced only .3 mm metal wastage in 30,000 operating hours. This amazing lack of corrosion exists despite the 732 C (1350 F) flue gas temperature entering the superheater and the 427 C (800 F) steam temperature leaving the superheater. The water tube walls have a most acceptable 0.1 mm metal wastage for the same time period. This high turbulence along with many other factors share the credit for no corrosion. See page 83 for a comprehensive discussion on corrosion.

Martin and Hagenholz personnel emphasized their rejection of any sidewall secondary air jets. Any sidewall jets, they claim, would cause CO to develop in the middle of the furnace.

The secondary air passes 22 nozzles in a single row of the front wall and a similar 22 nozzle row in the rear wall.

Readings of CO_2 are taken by using an instrument built by Landis and Gyr of Zug, Switzerland. The instrument is recalibrated every two weeks using a sample of known CO_2 concentration. Every year, the instrument is cleaned and the filter is changed. On June 8-10, 1977, the CO_2 readings varied between 8.2% and 11% (see the data - Page 62).

Reliability of the secondary air system has been excellent. The V-belts have not even been replaced after 30,000 hours. The nozzle jets have remained open and clear despite slag buildup on the rear wall.

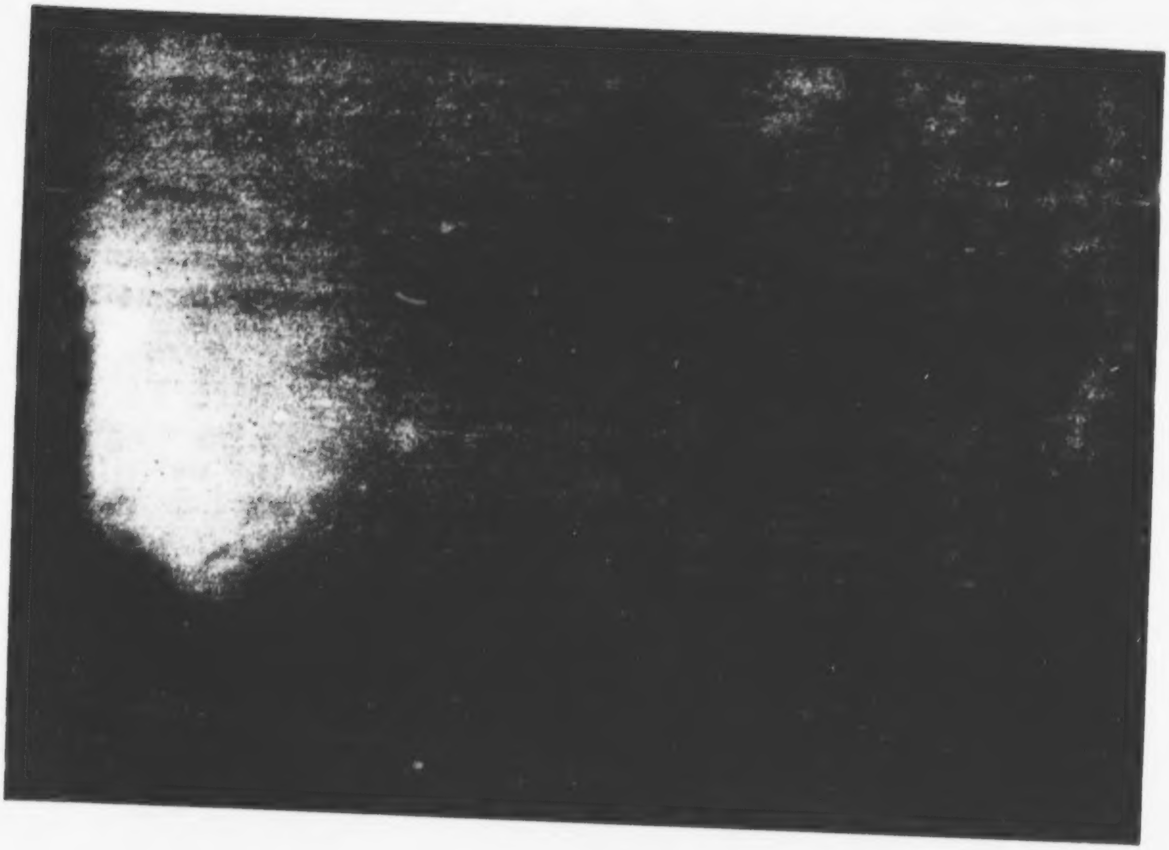


FIGURE 8-15. HAGENHOLZ UNIT #3 WHERE SECONDARY OVERFIRE IS PLENTIFUL

Burning Grate

The Martin #3 furnace is equipped with its unique reverse action reciprocating grate as depicted in Figure 8-16. The furnace, with its three parallel runs, is wide but quite typical for Martin installations. The unit is rated 21 tonnes (23.1 tons) per hour of refuse input.

The reader is referred to a previous discussion on Waste Storage and Retrieval where little concern is expressed for knowing exactly how much refuse is being fired at any one time. Nevertheless, for a period, precise measurements were taken and ratios were developed. One of these ratios is 2.41 tonnes of steam produced per 1.00 tonne of refuse consumed. This, by definition, is also 2.41 tons of steam produced per 1.00 ton of refuse consumed.

In a typical hour, 34 to 39 tonnes of steam are produced. Assuming 37 tonnes steam means that about 15.3 tons refuse was consumed.

Grate bars are made from 18% chromium steel. They are designed and assembled so that no more than two percent of the grate area is open for air flow. Thus, with separate air flow control in each of the fifteen air plenums and with the many small air holes, the air pressure drop can be kept at a very high level for maximum turbulence.

The total furnace width is 5.57 m (18 feet) and the length is 8.35 m (27 feet) for a total area of 44.9 m^2 (483 ft^2).

The first sign of bar breakage is usually siftings discharge problems. After a bar breaks, larger material falls into the plenum and eventually enough will plug the hopper.

Non-anticipated inspections are made upon breakdowns. Cursory-anticipated quick inspections are made every 1,000 hours. But the detailed anticipated grate inspections are made every 4,000 hours or twice per year.

In four years of running, grate bars caused emergency shutdown twice, resulting in five grate bars total to be repaired under emergency conditions. After three of the anticipated inspections, grate bars were replaced. In total, about 30% of the grate bars have been replaced leaving 70% of the original grate bars intact after 30,000 hours.

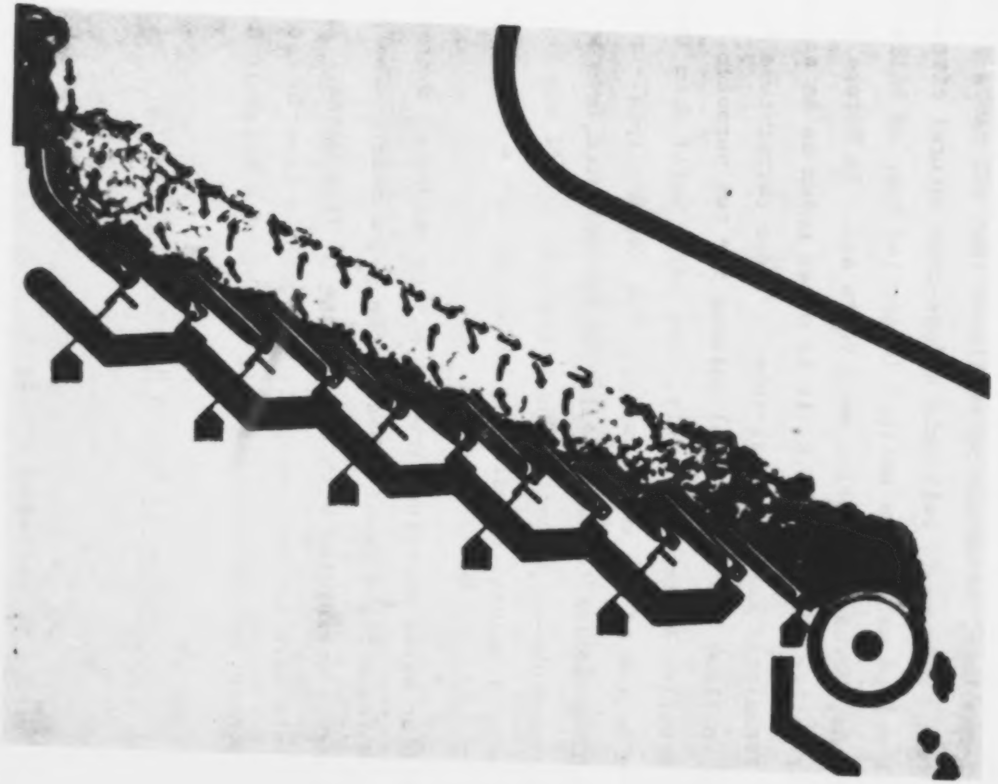


FIGURE 8-16. REFUSE AGITATION ACTION OF MARTIN GRATE
(Courtesy of Josef Martin Feurungsbau, Gmhh)

Complete Boiler

Before presenting details of the EVT (of Stuttgart, W.Germany) boiler, some general boiler items should be described. Figure 8-17 shows the furnace/boiler cross-sectional view of Unit #3. For those not familiar with this technology, it should be mentioned that all parts of the boiler are connected. Some would call this a "one-drum natural circulating boiler with welded water tube walls." (A similar type of boiler had been designed by Dr. Vorkauf of Berlin many years ago. In Europe it is called the Eckrohr boiler and in the U.S. it is often known as an econotube boiler. "Eckrohr" translated means "corner-tube." These corner-tube boilers use very large, hollow, and heavy steel columns for two purposes. First, they support the entire boiler. Secondly, they carry water down from the steam drum to the bottom of the water walls.) The Hagenholz-EVT-boiler is definitely not an "Echrohr-boiler"! This boiler is topsupported from a steelstructure and not corner-tube-supported! The boilers #1 and #2 are Echrohr boilers! This boiler is a natural circulating boiler and not a forced circulating boiler!

Boiler water entering from the boiler feedwater system passes through the following sets of tubes in the below order. The ordering is not necessarily correlated with the passage of flue gases. In fact, city officials have learned enough from Hagenholz experiences so that the third generation Josefstrasse unit will have a slightly different ordering.

Portions of Zurich Hagenholz Boiler #3

Economizer bundle at bottom of 4th Pass	1
" " " middle " " "	2
" " " " " " "	3
" " " " " " "	4
" " " top " " "	5
Water tube walls combustion chambers	6a
Water tube walls first pass	6b

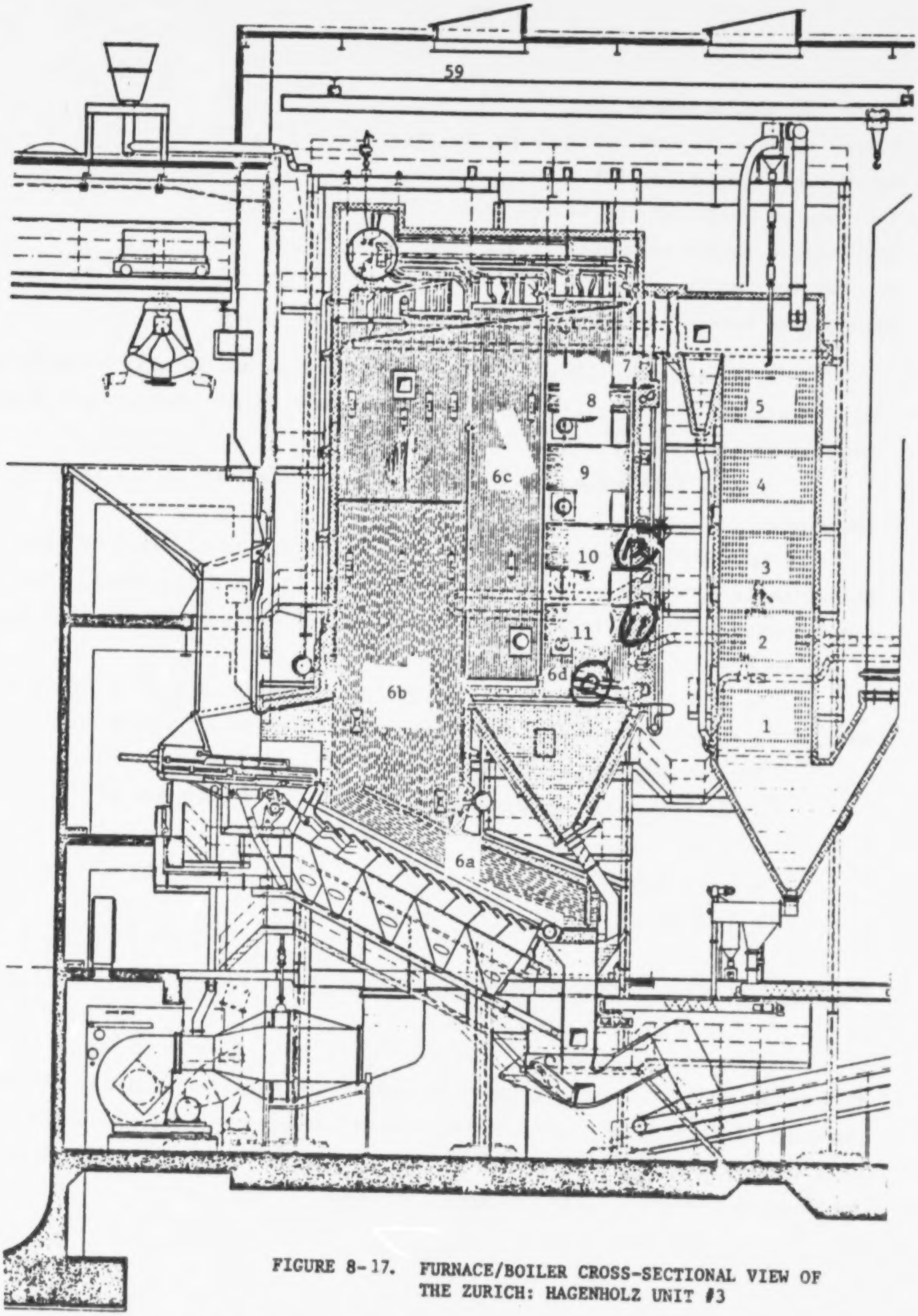

59
7
8
5
6c
9
4
10
3
11
2
6d
6b
1
6a

FIGURE 8-17. FURNACE/BOILER CROSS-SECTIONAL VIEW OF THE ZURICH: HAGENHOLZ UNIT #3

At Josefstrasse, the hottest superheater will be at position 10 in between two other superheaters.

Water tube walls second pass	6c
Screen tubes at bottom entrance to 3rd pass	6d
Superheater supporting tubes	7
Superheater bundle at top of 3rd pass	8
Superheater bundle at middle of 3rd pass	9
Superheater bundle at middle of 3rd pass	10
Superheater bundle at bottom of 3rd pass	11

At Josefstrasse (Figure 8-17), positions 11 and 12 will be reversed. This change will permit slightly cooler flue gases to hit the hottest steam temperature superheater.

Figure 8-13 shows the spacing and key dimensions of all of the tubes used.

Considering the complete boiler, the height is 28.7 m (94 feet), the width is 7.88 m (25.8 feet) and the depth is 15.9 m (52 feet). The final output is 38,200 kg/hr (84,216 lbs/hour) of steam at 38 bar (551 psi) at 420 to 427 C (788 to 800 F).

Assuming that the refuse energy input rate is 33 Gcal (131 MBtu) per hour, the volume heat release rate is 117 Gcal/m^3 - hour (13100 Btu/ft^3 - hour). The heating surface is as follows:

• Water tube walls, Passes 1,2, and 3	1,349 m^2
• Screen tubes	42 m^2
• Superheater	703 m^2
• Economizer	951 m^2
	3,045 m^2

One Day's Flue Gas Temperature, CO_2 Level and Steam Production Recordings

During our visit on June 9, 1977, several hours were spent in the control room. The steam flow (volume) chart showed relatively steady readings of 34.5 to 39 tonnes (38 to 43 tons) steam per hour. Actually, much of the time the readings were closer at 35 to 37.5 tonnes (38 to 41 tons) steam per hour. All readings are shown in Table 8-7.

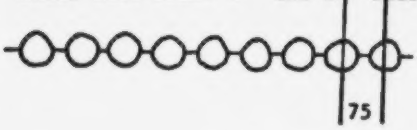
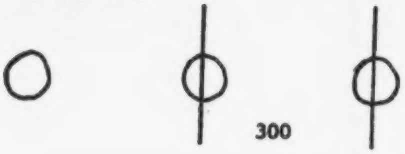
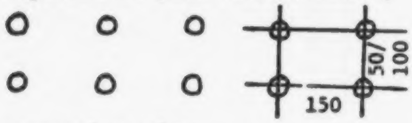
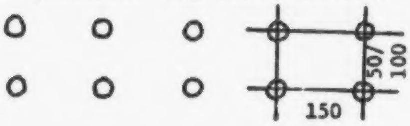
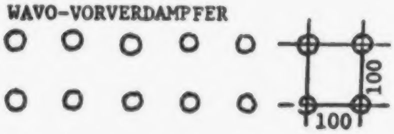
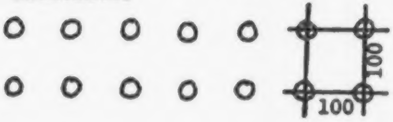
		Tube Diameter mm	Tube Thickness mm	Flue Gas Velocity Maximum	Average
Water Tube Walls 1st and 2nd Passes  	1st Pass	57	4.0	4.38	4.10
	2nd Pass	57	4.0	6.66	6.40
Screen Tube  		70	4.5	5.55	5.55
Superheater (Lower first bundle)  serpentine tubes		31.8	4.0	6.65	6.45
Superheater (Top three bundles)  serpentine tubes		31.8	4.0	6.25	5.75
WAVO-VORVERDAMPFER  serpentine tubes		38	4.0	7.00	6.45
Economizer  		38	4.0	6.10	5.5

FIGURE 8-18. BOILER TUBE SECTIONS LAYOUT AT ZURICH: HAGENHOLZ #3

TABLE 8-7 . FLUE GAS TEMPERATURES, CO_2 LEVELS, AND STEAM FLOW RATES RECORDED ON JUNE 9, 1977 AT ZURICH: HAGENHOLZ UNIT #3

	First Pass		Superheater Section				Economizer			
	Furnace Roof									
	Left	Right	Before Hottest Bundle	Before 3rd Bundle	Before 2nd Bundle	Before 1st Bundle	Before Economizer	After Economizer	CO_2 (%)	Steam Flow Tonnes/2 hr
1 a.m.	860	860	720	680	630	510	530	290	10	--
3 a.m.	740	780	720	690	640	510	540	287	9	73
5 a.m.	680	630	630	600	560	460	500	275	9.5	70
7 a.m.	780	790	730	700	640	510	540	285	9	72
9 a.m.	730	800	690	670	630	500	540	285	9	66
11 a.m.	730	760	710	690	640	510	540	285	11	71
1 p.m.	730	760	700	670	630	500	535	282	11	69
2 p.m.	730	750	700	680	635	500	540	290	8.2	71

Readings taken by Battelle researcher from charts and graphs on the day in question.

This Unit #3 had been cleaned 3,000 hours previously.

At 4:50 a.m. to 5:10 a.m., the flow suddenly dropped to 24.1 tonnes (26 tons) steam per hour owing to bulky waste which reduced the energy input. By 5:15 a.m. the steam flow rate had returned to 36.1 tonnes (40 tons) per hour. In a few minutes it peaked at 41.1 tonnes (43 tons) per hour; but only for a few minutes.

Later in the morning, between 9:00 a.m. and 10:00 a.m., there was a similar drop to 26 tonnes (29 tons) per hour and subsequent recovery. All this time, the steam pressure and temperature held a perfectly steady position; the pressure at an unchanging 62% of full scale.

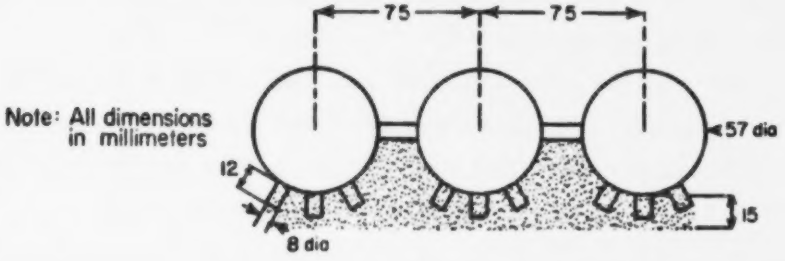
Flue gas temperatures, CO_2 levels, and two-hour steam flows are shown in Table 8-7 . These readings are for Unit #3 that has operated about 3,000 hours since the last cleaning.

Boiler Walls (Combustion Chamber--First, Second, and Third Passes)

The total boiler wall heat adsorption area is 1,349 m^2 (14,515 ft^2). Another 42 m^2 (452 ft^2) could be added if one considers the large screen tubes to be part of the wall. Data were available on furnace volume up to the screen tubes (and not the third pass) that indicate a volume of 472 (16,670 ft^3). Considering the first pass alone, the volume is 340 m^3 (12,000 ft^3) and the heating surface is 330 (3550 ft^2).

The wall tubes are 57 mm (2.2 in) in diameter and are 4 mm (0.16 in) thick. The center-to-center spacing is 75 mm (2.9 in). In the first pass, the maximum flue gas velocity is 4.38 m (14.3ft)/second with 4.10 m (13.5 ft)/ second being more normal. Following in the second pass, the maximum flue gas velocity increases due to its smaller cross-sectional area, to 6.66 (22 ft)/ second with 6.40 m (21 ft)/second being normal.

The wall construction is termed "welded fin". The fins connecting the tubes are extruded with the tube. The procedure was developed by EVT of Stuttgart. At the factory small steel studs are welded to the furnace side of the tubes to a density of 2000 studs/m^2 (186 studs/ft^2). The stud orientation is radially out from the tube center. Therefore, with respect to the relatively flat wall, the stud angles are different and result in a better adhering surface; as shown below:



Each stud is 12 mm (0.5 in) long and 8 mm (0.3 in) in diameter.

After the studded tubes had been installed at Hagenholz, plastic silicon carbide (SiC) was covered over the studs to a thickness of 12-15 mm (0.5 to 0.6 in). The use of studs covered with SiC is only in the combustion chamber and the lower 2/3 of the first pass as depicted in the previous Figure 8-2. Mr. Baltensperger commented that the SiC should extend one or two meters beyond where flames might be expected.

Figure 8-19 is a picture taken of the studded SiC-covered walls taken from across the active combustion chamber in Unit #3. As can be seen, slag very seldom adheres to the SiC. Small amounts of slag will accumulate but will fall off.

Sootblowers are not used in the first and second passes so that any chance of a sootblower malfunction causing a tube rupture is eliminated.

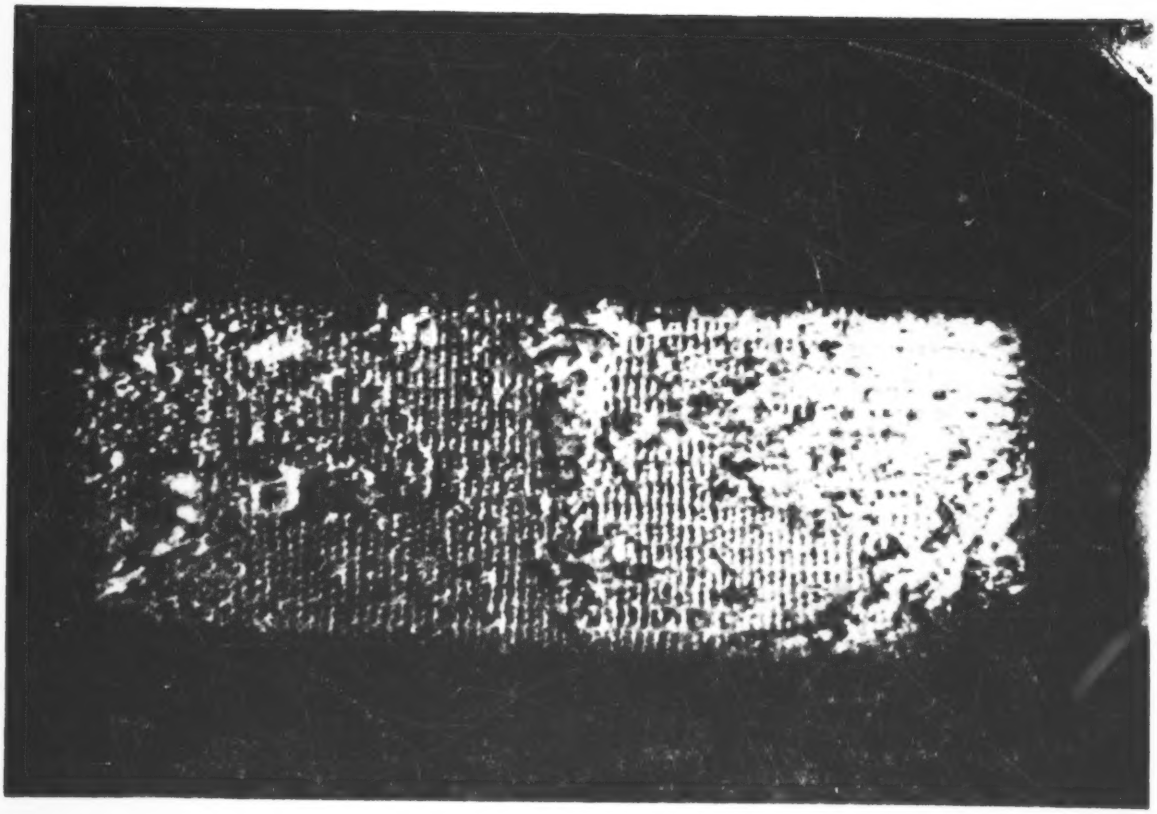


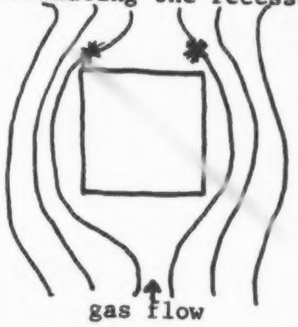
FIGURE 8-19. FIRST PASS WALLS COVERED WITH SILICON CARBIDE OVER WELDED STUDS: SHOWS REJECTION OF SLAG FROM WALLS OF ZURICH: HAGENHOLZ (Battelle Photograph)

Officials have been most pleased with results. After 30,000 hours, the combustion chamber wall tubes have experienced only .1 - .2 mm (0.004 to 0.008 in) metal wastage. Finally in 1978, after about 40 000 hours operation and no tube bursts, the superheater was replaced, "to be on the safe side".

The temperature at the end of the flame tips is 1000 C (1832 F). Two-thirds up the first pass (where the SiC stops), the flue gas temperature falls to 800 C (1472 F). Using the highly-thermally efficient SiC, a heat release rate of 117,000 Kcal/m^3 is possible based on a heat input rate of 33 Gcal/hour.

The SiC surface is rarely repaired on the 1000 hour inspections. SiC might be repaired on the 4000 hour planned inspections. Studs and SiC might be repaired once per year during major overhaul.

An additional design recommendation to reduce wall tube corrosion is to place the vertical man-hole doors flush with the inside surface of the furnace wall. Eliminating the recessed cavity will reduce dust erosion.



Screen Tubes

The normal function of screen tubes is to facilitate water circulation and to hold the walls in alignment.

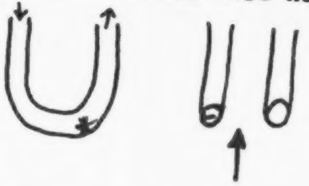
However, at Hagenholz, screen tubes have a third important function. To further reduce corrosion, flue gases pass through large, gently sloping screen tubes at the base of the third pass. These circulating boiler-water carrying tubes provide a modest chill to the flue gases. Flue gas temperatures are reduced slightly to the benefit of superheater life. To some extent, these easy-to-replace screen tubes might be called "sacrifice screen tubes."

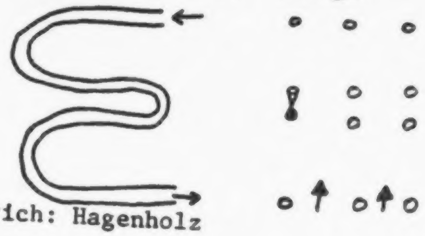
The tubes have a diameter of 70 mm (2.7 in) and a thickness of 4.5 mm (0.18 in). They are spaced 300 mm (12 in) apart. The maximum design and the average flue gas velocities are both 5.55 m/sec (18.2 feet/sec).

Superheater (and Attemperator)

The superheater placement can be seen in either the previous Figure 8-18 or in the following Figure 8-20. Four horizontal tube bundles are connected as shown on the following figure.

The interview turned again to the differences between the evolving Paris: Issy plant and the mature Zurich: Hagenholz Unit #3. In Paris, the superheater tubes were hung vertically in a "harp" design.


Paris: Issy


Zurich: Hagenholz

The Paris design, (built in 1961) it is theorized, would develop water droplets in the bottom of the loop that would act as an insulation blanket. Proper heat transfer could not take place and metal temperatures would rise further in the high temperature corrosion range.

At Zurich: Hagenholz, however, (designed in 1971) the steam flow is always downward such that nothing can become trapped. Heat transfer thus takes place and corrosion is reduced. The heat transfer area is 703 m^2.

The lower and hotter bundles are made from 15 Mo 3 steel while the upper and cooler bundles are made from 35.8 II steel. The tube diameter is 31.8 mm (1.2 in) while the thickness is 4 mm (0.15 in). The horizontal centerline spacing is 150 mm (5.9 in) and the vertical spacing within a bundle is 50/100 mm.

The lower hottest first bundle has a maximum flue gas velocity of 6.65 m/sec (22 feet/sec) and average velocity slightly less at 6.45 m/sec (21 feet/sec). The top three bundles, however, have a slower velocity at a maximum of 6.25 m/sec (20 feet/sec) and an average velocity slightly

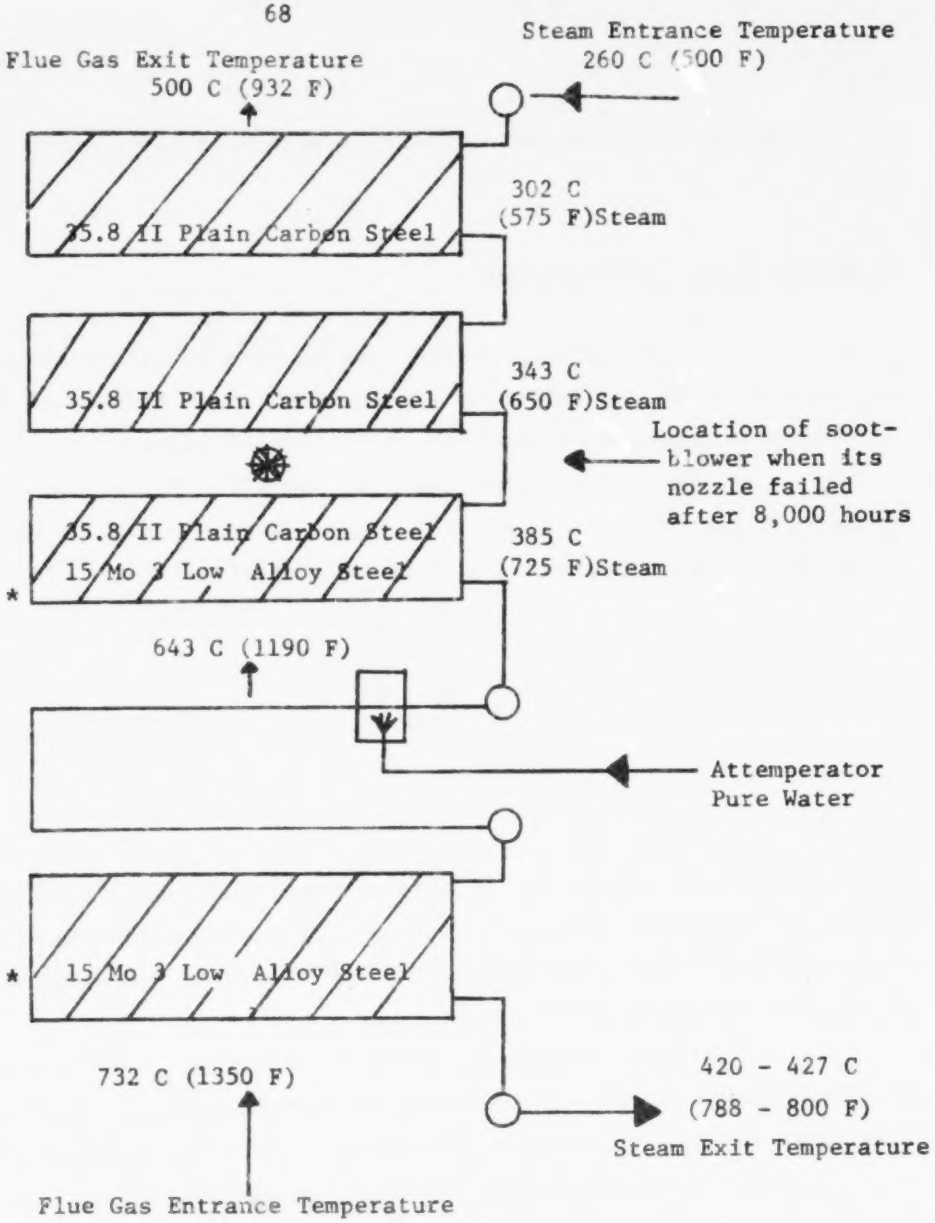

Flue Gas Exit Temperature
500 C (932 F)
Steam Entrance Temperature
260 C (500 F)
35.8 II Plain Carbon Steel
302 C
(575 F)Steam
35.8 II Plain Carbon Steel
343 C
(650 F)Steam
Location of soot-blower when its nozzle failed after 8,000 hours
35.8 II Plain Carbon Steel
15 Mo 3 Low Alloy Steel
*
385 C
(725 F)Steam
643 C (1190 F)
Attemperator
Pure Water
*
15 Mo 3 Low Alloy Steel
732 C (1350 F)
420 - 427 C
(788 - 800 F)
Steam Exit Temperature
Flue Gas Entrance Temperature

FIGURE 8-20. SUPERHEATER FLUE GAS AND STEAM TEMPERATURE AND FLOW PATTERNS AT ZURICH: HAGENHOLZ

* The last and lowest loop of the 3rd bundle and the entire 4th bundle are made with 15 Mo 3 low alloy steel.

less at 5.75 m/sec. The reason for the lower velocity with the same cross-sectional area of flow is the cooling of the flue gases.

To better control boiler exit steam temperature (plus and minus 5° C), an attemperator injects varying amounts of deionized, deaerated, and demineralized pure water. In general this must be even more pure than boiler feedwater. The injected water must be pure; otherwise, scale is likely to build up in the superheater tubes. The point of injecting is shown in Figure 8-16 as being between the lowest and the next bundle.

One might ask why the attemperator (desuperheater) water must be even cleaner than the very clean boiler feedwater. The answer is that the attemperator water (under 100 C, 212 F) must suddenly convert to steam (at 400 C, 788 F). As a result, the minerals formerly dissolved in the water suddenly become solid particles. The higher concentration of these particles will accumulate on the downstream superheater tubes.

About 38,200 kg/hr (84,276 lb/hr) of steam at 38 kp/cm^2 (551 psi) are produced.* Note that the steam enters the superheater at 260 C (500 F) and then exits with a temperature of 420-427 C (788 to 800 F) at the very bottom of the third pass. In a later design, Martin tried a slightly different configuration as shown in Figure 8-17. In this design, the hottest tubes are the upper row of tubes in the first bundle. This design was likely motivated by the excessively high percentage of total plastics, being 10 to 15 percent of the refuse input.

The advantage is that a slightly cooler temperature flue gas hits the hottest steam tube. Thus, the metal and tube deposit temperature is less and there will be less corrosion. Zurich and Martin officials apparently believe that a slight reduction in exit steam temperature is more than compensated by a reduction in superheater metal wastage. Hence, the new Josefstrasse plant under construction will use this design.

Boiler Cleaning. As mentioned previously, there has (with one sootblower incident exception) been virtually no corrosion of superheater tubes in 30,000 hours. At 30,000 hours, metal wastage was determined to be only .3 mm (0.013 in) at many points around the tubes.

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*kp is translated "kilogram force"
1 kp/cm^2 = 1 bar = 14.504 psi = 10,000 Newtons/m^2

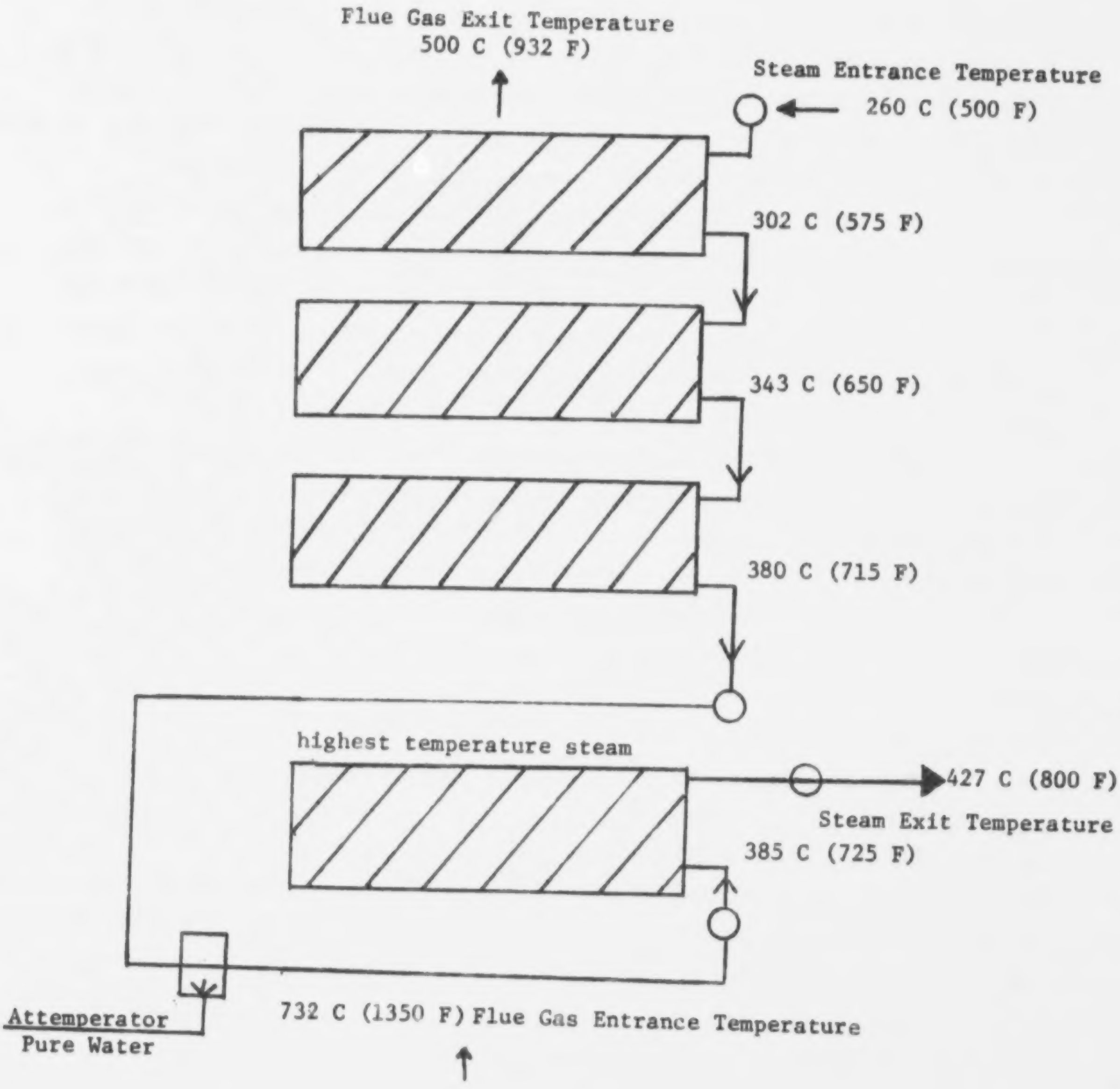
Flue Gas Exit Temperature
500 C (932 F)
Steam Entrance Temperature
260 C (500 F)
302 C (575 F)
343 C (650 F)
380 C (715 F)
highest temperature steam
427 C (800 F)
Steam Exit Temperature
385 C (725 F)
Attemperator
Pure Water
732 C (1350 F) Flue Gas Entrance Temperature

FIGURE 8-21. SUPERHEATER FLUE GAS AND STEAM TEMPERATURE AND FLOW PATTERNS AT THE NEW ZURICH: JOSEFSTRASSE PLANT

The one exception occured after only 8,000 hours. The sootblower was manufactured by Forest and Bergaman of Brisstol, Belgium. A nozzle on a fixed position, rotary sootblower fell off. As a result, high pressure compressed air blew directly onto the tube sides. The nozzle failure was detected and the tubes were inspected. None of the superheater tubes were burst but they had sufficient metal wastage to motivate replacement. Thus, after 8,000 hours, twenty (20) tube sections, averaging 5 m (16 feet) per tube each, were replaced. There have been no sootblower problems since.

The compressed air sootblowers are used daily. The two air compressors supply two storage air tanks each 15^3 with air at a 30 bar (450 psig). The air released at the sootblower nozzle is at 15 bar (225 psig). Officials expressed their preference for superheater sootblowing with compressed air over steam even though the air compressor costs about SF 250,000. As an official stated, "We use air for sootblowing. If we used 10 tonnes steam per hour for sootblowing, we wouldn't be able to sell it."

Once (or twice) per year, each Hagenholz boiler is manually cleaned by the Hutte Company of Recklinghausen, West Germany (near Essen). Four or five (4 or 5) men spend seven or eight (7 or 8) days cleaning one boiler. An alkali chemical is used. Sandblasting may be used for selected hard to dissolve deposits. The procedure is basically as follows for most deposit areas.

1. Spray alkali (soak, no pressure)
2. Rinse with water
3. Spray alkali (second soak)
4. Rinse with water
5. Scrub with brushes and other tools
6. Sandblast difficult deposits

Cleaning all the tubes (walls and bundles) in all four passes normally costs about 25,000 SF ($10,000). The dirty water coming out at the boiler bottom has a Ph of about 2 so lime must be added.

Plant staff have been experimenting with an "unbalanced compressed air vibrator" for cleaning the superheater. Every two minutes, the upper three bundles are vibrated. Every second or third months, they perform a variation and interrupt the procedure for a half day.

At the Hamburg: Borsigstrasse plant, the bundle wall anchors are hit with a sledge hammer once per week.

Convection Section

Hagenholz Unit #3 does not have a regular boiler convection section because of the extensive four bundle superheater, the five bundle economizer, and the four passes of water tube walls.

Economizer

The five economizer bundles are made of 35.8 II plain carbon steel. The centerline spacing in both directions is 100 mm (4 in). Each tube is 38 mm (1.5 in) in diameter and 4.0 mm (0.16 in) thick. The maximum flue gas welocity is 6.1 m/sec (20 feet/sec) while the average velocity is 5.5 m/sec (18 feet/sec).

Boiler Water Treatment

Boiler water is carefully monitored and treated. Detailed water tests are made once per month. For deoxidation, N_2H_4 (Hydrazine) is used. Sometimes Levaxin, manufactured by Bayer Chemical, is used rather than Hydrazine.

Water usage per refuse tonne handled over 52 weeks is shown in Figure 8-22. The primary water use is the ash quench. Presumably, the ash content rises in the Spring and Summer as vegetation, earth and construction material waste increases.

Boilers for Firing With Fuel Oil, Waste Oil, and Solvents

Hagenholz is equipped with two Sulzer (of Zurich) fossil fuel boilers; one for virgin Number 2 fuel oil and another boiler for both

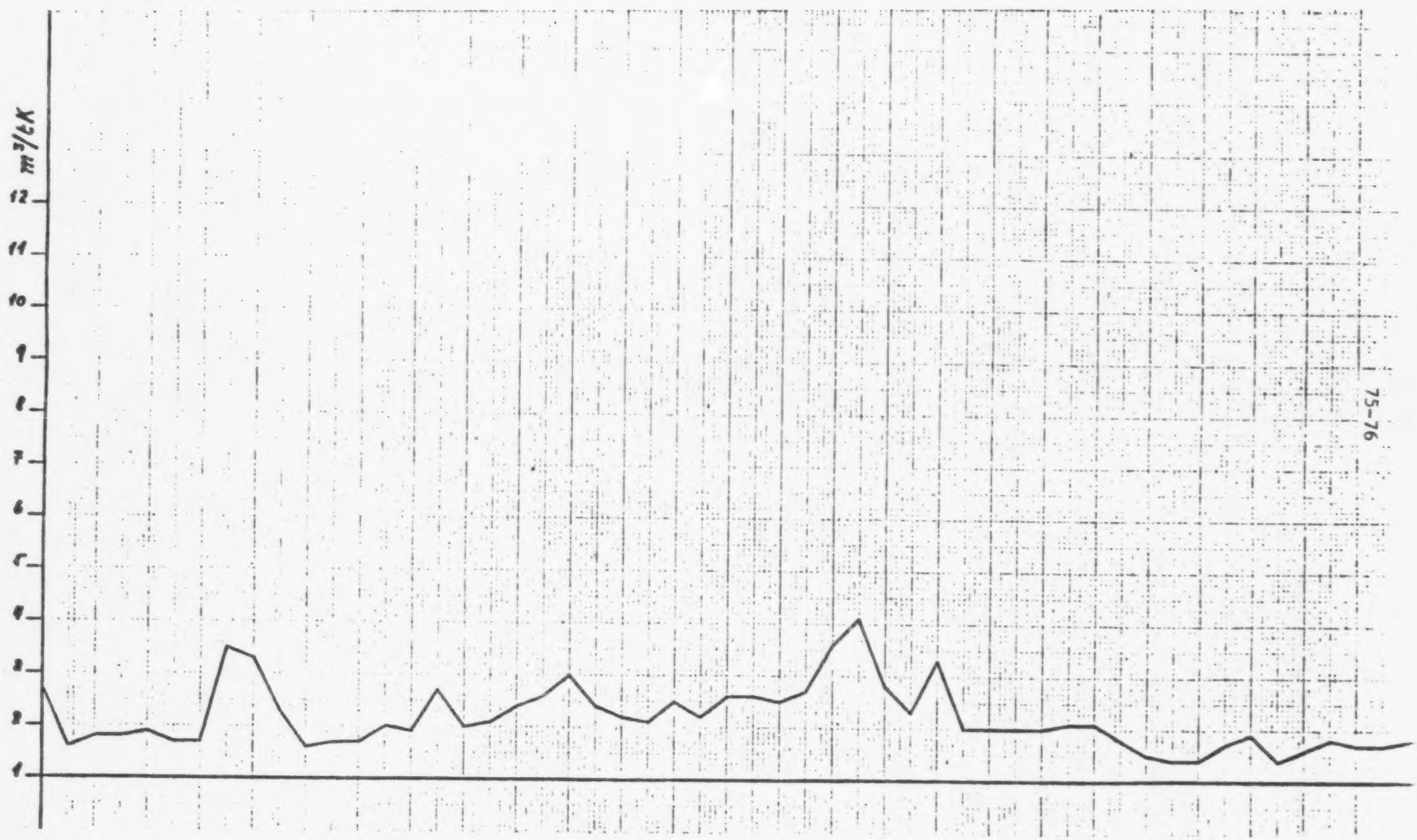

FIGURE 8-22. WATER CONSUMPTION PER TONNE OF REFUSE CONSUMED IN 1976

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waste oil and waste solvents. Some operating figures previously appearing in Table 8-6 are repeated below:

	Annual Totals	
	1974	1976
Number 2 fuel oil fired boiler #1 (operating hours)	201	182
Waste oil and solvent fired boiler #2 (")	1,486	2,099
Total (boiler - operating hours)	1,687	2,281
Number 2 fuel oil fired boiler #1 (tons of steam)	1,413	1,404
Waste oil and solvent fired boiler #2 (")	11,244	13,192
Total	12,657	14,596
Number 2 fuel oil burned (tons)	109	108
Waste oil burned (tons)	794	1,102
Waste solvents burned (tons)	71	113
Total	974	1,323
Waste oil collected (tons)	1,654	1,801

It would be incorrect to label these activities as co-firing. The refuse burning areas are not connected at all to the oil burning areas. Max Baltensperger feels very strongly that no other fuel should be fired in the same combustion chamber as refuse because of inevitable problems of ash deposits on boiler tubes.

The Number 2 fuel oil boiler is only used to preheat the boiler and the air preheater (for the benefit of the electrostatic precipitator). The waste oil, however, is a completely separate system devoted to waste oil destruction and energy recovery.

Readings of CO_2 and opacity (Ringleman scale) are used to control these oil burning systems. There have been corrosion problems in the steel stack of these boilers.

The previous Figure 8- 8 shows the general layout of the solvent and waste oil preparation area. The waste oil is heated and decanted. The oil, water, and sludge are pulled off separately. The sludge at the bottom of the decanting tank is mixed with the municipal solid waste in the pit. The oil overflow goes to the boiler.

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LITTLE OR NO CORROSION AT ZURICH: HAGENHOLZ UNIT #3

The occurrence of little or no corrosion at the Zurich: Hagenholz Unit #3 has been of interest to professionals as the 30,000 operating hours since original construction in 1973 continue to increase. From 1973 to June, 1977, not a single boiler tube in any section has failed.

The most serious incident was when a superheater section fixed rotary sootblower nozzle failed and sent too much compressed air directly onto superheater tubes. The nozzle failure was discovered after 8,000 hours and the area was examined for metal thickness. They replaced 20 tubes of an average 5 m (15 feet) length.

A recent check in April, 1977, showed that the original superheater tubes had metal wastage of only 0.3 mm. The water tube walls of the second pass had only 0.1 to 0.2 mm metal wastage on the original tubes.

What accounts for this amazing lack of corrosion despite a relatively high steam temperature? In summary, the threat of corrosion was well known before construction began and many steps (27 were discussed with Battelle staff while in Zurich) were taken to minimize the metal wastage. Metal wastage can occur chemically in the form of corrosion or physically through erosion.

This section describes these 33 steps, discusses Mr. Richard Tanner's theory, Battelle's general theory and finally Dale Vaughan's explanation of chloride actions as a reason for no metal wastage at Hagenholz.

33 Design Steps Taken at Hagenholz to Reduce Metal Wastage

Four general causes of metal wastage are important: dew point corrosion, high temperature corrosion, chlorine corrosion and physical erosion. They will be referred to often in the following listing of how Max Baltensperger and Heinz Kauffman cooperatively designed the unit for most successful operating results.

At a social gathering, Walter Martin was asked, "Why doesn't Hagenholz Unit #3 corrode?" His initial casual remark was "Good Management". Later upon reflection, he added nine other reasons. Other reasons came out of the normal interviewing process.

Management

1. The original design spirit at Zurich was that there was a no set limit as to spending for the best (efficient and reliable) boiler that money could buy.
2. The refuse input averages 72.4% of the maximum burning rate. "You ought to build the best plant possible and then run it at 80% of capacity".
3. Excellent management ensures that the properly designed plant is observed, monitored, and controlled as it is intended.
4. Rotating job positions for each man enhances his understanding of the complex plant and his spirit to run it properly.

Automatic Control

5. The Martin "black box" sends instantaneous furnace roof temperature readings to the feeder and grate controls. As a result, flue gas, metal surface, and steam temperatures are kept within limits and high temperature corrosion is avoided.

Start-up Procedures

6. The standby boiler (Number 2 oil or waste oil) is always started before the refuse is fired and the steam heats primary underfire air in the steam air preheater to 150 C--above the dew point temperature.
7. This same standby oil-boiler supplies steam to the refuse boiler to preheat the tubes above the dew point temperature.
   The effect of the oil-fired steam is to raise the boiler surface temperatures above the dew point temperature so that this type of corrosion does not affect either the boiler, the electrostatic precipitator, or the stack.

Refuse Handling

8. Refuse is thoroughly mixed by the crane operators so that a more uniform refuse fuel is available that will not cause wide swings in flue gas temperatures.

9. The feeders are designed to introduce controlled amounts of refuse into the furnace and not permit uncontrolled cascading that would cause poor burning and formation of harmful CO.
10. The Martin grate, with its reverse action motion, gently (without cascading--except for tires and stumps) rotates the refuse for exposure to flame and combustion air.

Secondary Air

11. The front and rear-wall secondary overfire-air jets are properly aimed to develop the desired turbulent pattern. Flame lengths are kept short and few rise into the first pass.
12. No side wall air is permitted where inadequate mixing might allow CO to form. (However, this is not meant to criticize Kunstler or Didier air wall blocks).
13. Secondary air at 500 to 600 mmWs causes intense turbulence so that virtually all CO is eliminated before the flue gases leave the combustion chamber. Alternating reducing - oxidizing atmospheres are eliminated.
14. The secondary (overfire air) from the neighboring rendering plant "may" contain reduced sulfurs, etc., that may reduce corrosion by forming sulfate deposits on the tube, thus reducing chlorine tube deposits. However, the concentration of sulfur is believed to be low and more investigation is needed to confirm any hypothesis. The ammonia ppm is often high and its effect, if any, on corrosion is not known.

Furnace Walls

15. The walls of the combustion chamber and the lower 2/3 of the walls in the first pass are coated with Silicon Carbide (instead of bare plain carbon steel) that was properly applied and bonded. No flame passes beyond this point.
16. The second pass is very large so that more heat is absorbed into the walls.

17. The flue gases flowing in the large second pass are at a lower velocity which reduces the erosive effect of the particulates in the gas as it hits the first row of superheater tubes.

Superheater

18. The superheater is positioned in the third pass (and not the first or second passes) so that cooler flue gases, with little or no CO, hit the tubes.
19. The superheater tubes are horizontal flowing downward (and not vertically hanging). Thus, stagnant water pockets cannot form to interrupt heat transfer.
20. The superheater tubes are in line (and not staggered) so that flue gases can more easily pass.
21. The superheater metallurgy is 15 Mo 3 in the lower two bundles and 35.8 II in the upper three bundles instead of plain carbon steel, 35.8 I.
22. The attemperator (desuperheater) between the lowest superheater bundle and the next bundle inserts pure demineralized water when steam temperature rises above a certain limit. Thus, steam temperature and pressure (but not flow rate) can be kept constant plus or minus 5° C.
23. The entire boiler is designed so that the average superheater exit steam temperature is 420 C (788 F).

Economizer

24. The economizer originally equipped with a shield on the first tube row of the first bundle, was later augmented with more shielding on the second row of the first bundle.
25. The economizer is especially large to both recover energy and to reduce flue gas temperatures entering the electrostatic precipitator.
26. The plant used for test purposes is an "unbalanced compressed air pneumatic hammering vibrator".

27. No sootblowers are used in the first and second passes.
28. Compressed air (and not steam) sootblowers are used in the superheater section. Thus, injurious slugs of water lying in inactive sootblower pipelines cannot harm the tubes upon startup.
29. The sootblowers in superheater section are fixed-rotary (and not retractable). Hence, the nozzles are always oriented properly and not directed right on the steam tubes. The sootblower jets are fixed just underneath the tube bundle.
30. The boiler is manually cleaned with an alkali every 4,000 hours.
31. Sandblasting is limited to removing only difficult tube deposits.
32. With the lower flue gas temperatures in the first 1000 hours after cleaning, a ferrous sulfate $FeSO_4$ might have formed instead of the more harmful $FeCl_2$.
33. The economizer is cleaned with falling steel shot (and not by sootblowers) thus avoiding potential problems.

Theory of Corrosion Supplied by Richard Tanner Formerly of Von Roll

Figure 8-23 was supplied to Battelle by Mr. Tanner, Von Roll's top refuse-fired steam generator expert for many years before retiring. It shows corrosion threat (abstractly without any numerical reading) on plain carbon steel as a function of tube metal temperature.

General Theory of Temperature and Chloride Corrosion as Supplied by Dale Vaughan of Battelle

Early in this project, Dale Vaughan was asked to summarize his theory of how gases, metal salts, chlorine and sulfur react at different temperatures to cause corrosion. The following is his reply so carefully worded that it may have to be reread.

> "The boiler tubes are exposed to the normal combustion gases CO_2, CO, HCl, small amounts of sulfur oxides and organics, excess air, plus vapors and solids of inorganic compounds. The initial reaction is undoubtedly the formation of a thin oxide layer on the boiler tube which is quickly coated with a deposit containing large amounts of chlorine identified as a mixture of potassium and sodium chloride with smaller amounts of heavy metals. Hence, the tube metal is no longer exposed to the gaseous combustion products but instead is exposed to the deposit and/or the products of its reaction with the gases.
>
> Studies of deposits after long exposure to incinerator combustion products have shown that the chlorides are converted to sulfates and that the chlorine content is thus reduced significantly except at the metal surface when $FeCl_2$ has formed. The iron oxide layer is no longer in contact with the metal surface, but instead chlorine is now the corrosive species.

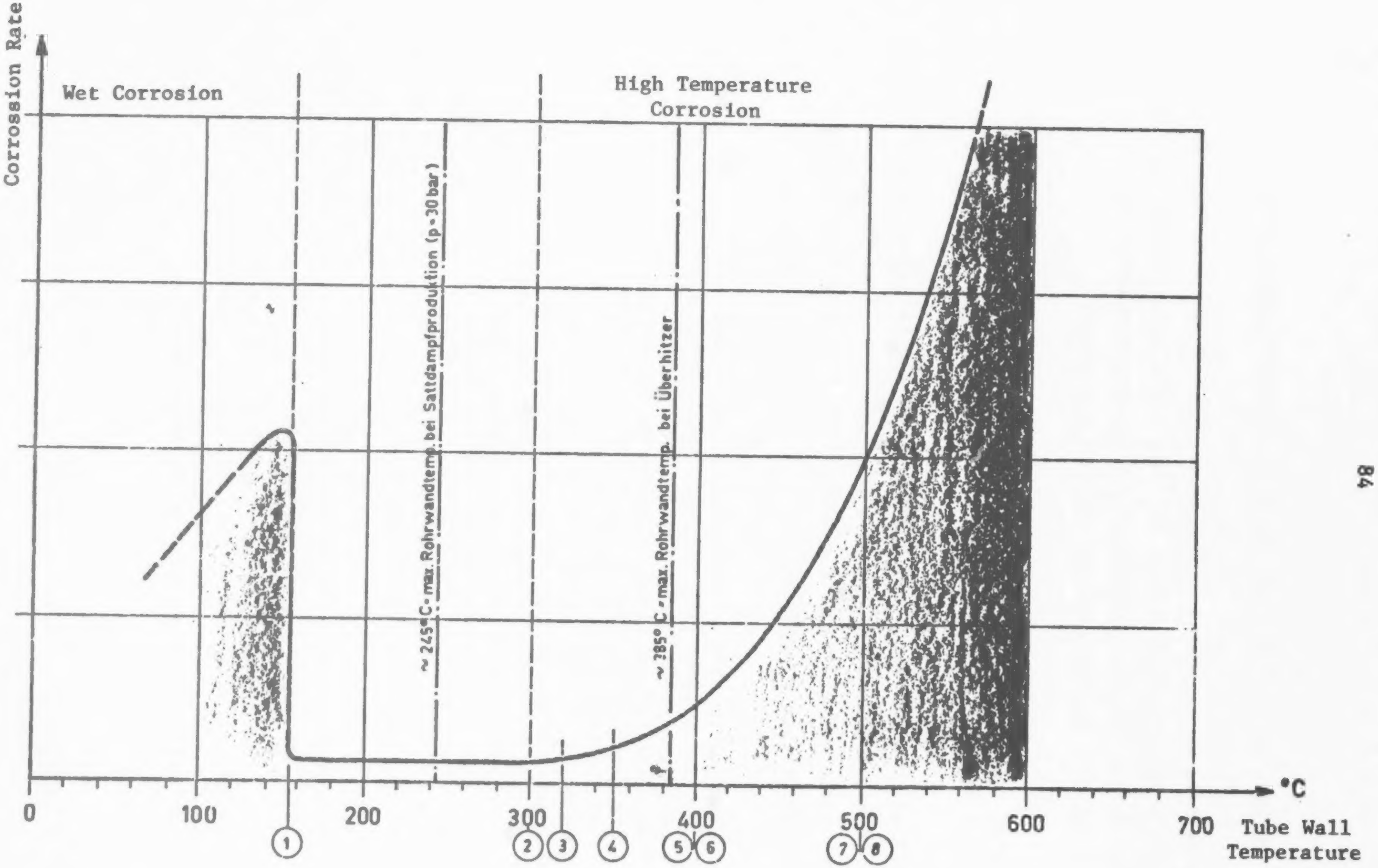


FIGURE 8-23. CORROSION AS A FUNCTION OF TUBE TEMPERATURE

①-⑧: Specify Various Ways For Corrosion To Occur

> Battelle's corrosion data show that wastage of carbon steel increases rapidly at about 400 F and again at 800 F. The first increase is attributed to chloridation and the second to sulfidization. The first increase coincides with the rapid attack of iron by elemental Cl_2 as shown by Brown, DeLong and Auld. Furthermore, their studies show that rapid attack of iron by HCl does not occur until a temperature of about 900 F. Therefore, it is doubtful that the HCl content of the combustion products is a significant contributor to metal wastage in the temperature range where chlorine is the corrosive species.
>
> However, as expected, Cl_2 has not been detected in combustion gases but this does not eliminate its existence as a product of the conversion of MCl_2* to M SO_4. This occurs mainly in deposits which are retained on boiler tubes and exposed for sufficient time to the hot gases containing low concentrations of sulfur oxides. When the CL_2 is released from the MCl_2 deposits at the metal surface the attack is very rapid. The Battelle studies have shown that by increasing the sulfur in the fuel M SO_4 forms rather than MCl in the fuel bed and combustion chamber, little or no chlorine is found in the deposit and the metal wastage is markedly decreased even though the HCl in the combustion gases is the same or perhaps increased some. SO_2 emission increases some but not rapidly."

---

* The letter "M" refers to any metal that might bond with CL_2 or SO_4.

Upon return to Battelle from Zurich, Mr. Vaughan was presented with specific data regarding conditions at Hagenholz Unit #3. He had the following response as summarized below:

> He examined the charts showing weekly average temperatures for July 1, 1973, to February 23, 1974 (Figure 8-9), and the period February 17, 1977 to June, 1977 (Figure 8-10). He believes the important factor is that early in both periods, namely, the first 1000 hours after tube cleaning, all flue gas temperatures were lower than later on in the 4000 hour cycle. Figures are summarized below.

	Hours			
	100	1000	2000	4000
Flue Gas Temperature Leaving Furnace	610°C	675°C	800°C	780°C
Flue Gas Temperature Entering Superheater	510	575	675	750
Flue Gas Temperature Entering Economizer	400	470	490	600
Flue Gas Temperature Leaving Economizer	225	265	250	260

The metal temperatures are, of course, much lower. The result is that the metal temperatures were low enough so any $FeCl_2$ that has been formed had time to convert to a ferrous sulfate, $FeSO_4$, thus, providing a protective coating immediately adjacent to the tube. The later high temperatures were thus not harmful because the sulfate coating shielded the tube from any later deposition and decomposition of chlorides.

The remarkable freedom from corrosion on Unit 3 appears to confirm Vaughans theory which has been discussed earlier. It was developed by Vaughan and his colleagues in laboratory and field research sponsored by EPA at Battelle since 1969.

ENERGY UTILIZATION

Energy utilization at Zurich: Hagenholz is among the most advanced in Europe. Max Baltensperger repeatedly pointed out that Hagenholz is primarily an energy plant. The plant is integrated with the other conventional fossil fuel district heating and electricity plants. A new oil fired energy plant is located nearby. The total story involves following energy media:

Hagenholz Refuse Fired Steam Generator

High temperature steam for electricity production (steam extraction - condensing turbo generators)	420 C (788 F)
Medium temperature steam for district heating (Kanton, the municipal district heating system)	260 C (500 F)
Hot water for district heating (EWZ, the investor-owned public utility for electricity and district heating)	130 C (266 F)
Hot water for a State hospital (sterilizing), small factory in Hagenholz, the railroad station, and perhaps the Technical University (5 km/line)	130 C (266 F)
Electricity for the two networks (Kanton and EWZ)	11,000 volts
Electricity for internal use, truck garage, and workshop	220 v and 380 v
High temperature steam for the rendering plant	420 C (788 F)

New Oil Fired Energy Plant

Hot water for district heating (Kanton, the municipal owned district heating system)	180 C (356 F)

Figure 8-24a shows the electrical power generation room and some of its equipment. The full energy product schematic for the plant is shown on the same page in Figure 8-24b.

Figures 8-25 and 8-26 are also two separate figures on one page. Figure 8-25 presents a relatively flat picture of total steam produced per ton of refuse consumed during the 52 week year. The average is 2.41 tonnes of steam produced per one tonne of refuse input.

Figure 8-26, showing kWh electrical sales per tonne of refuse consumer, however, does have a substantial seasonal pattern that compliments the district heating pattern. The philosophy is that district heating demand is the first priority and electrical production is second. The two electrical networks can absorb as much refuse produced electricity as can be generated. The reverse pattern for district heating appears later in Figure 8-26.

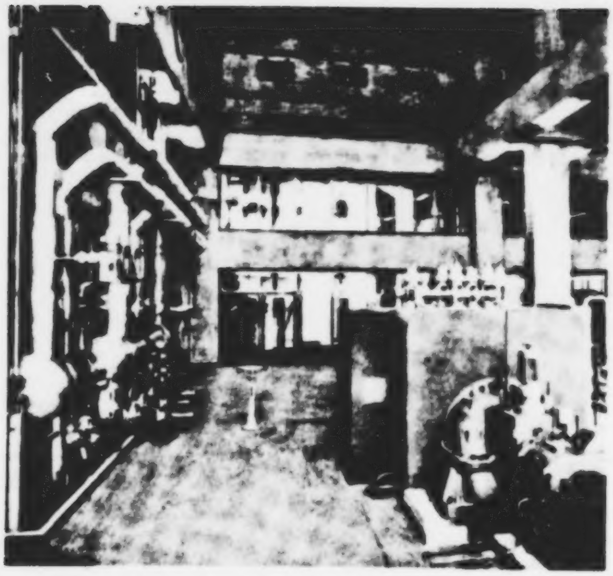
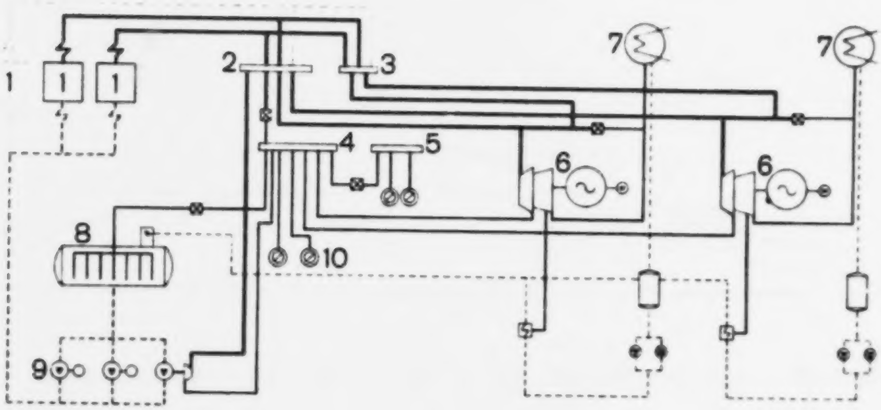


FIGURE 8-24a. ELECTRICAL POWER GENERATION ROOM



1. Furnace/Boilers
2. High pressure distribution valve
3. Governing valve
4. Medium pressure distribution valve
5. Low pressure distribution valve
6. Turbogenerator
7. Air condenser
8. Feedwater storage and deaerator
9. Feedwater pump
10. Steam for district heating

FIGURE 8-24b. STEAM AND BOILER FEEDWATER FLOW PATTERN EXTERNAL TO THE ZURICH: HAGENHOLZ BOILER

1976

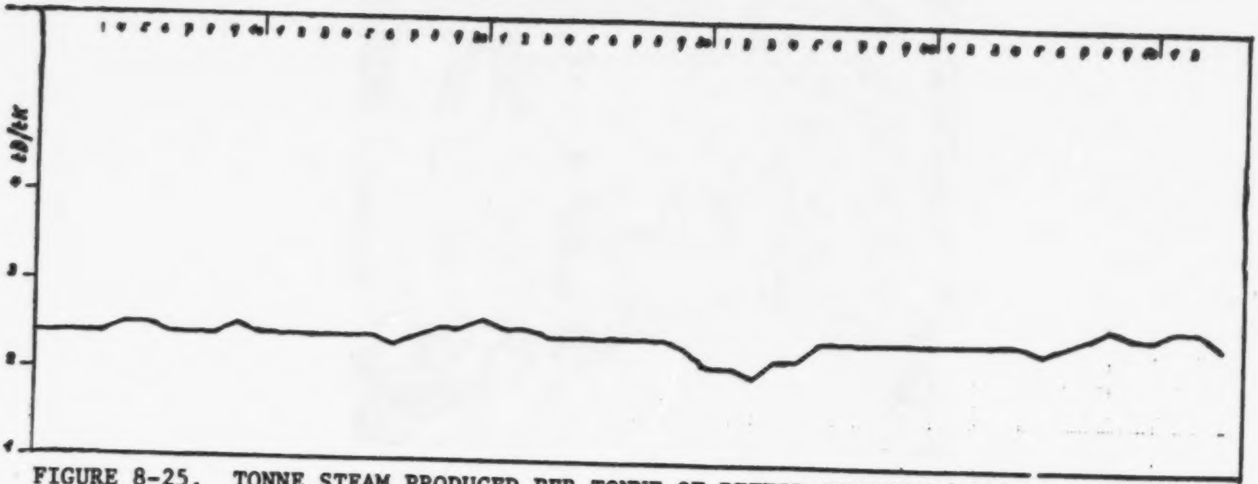


FIGURE 8-25. TONNE STEAM PRODUCED PER TONNE OF REFUSE CONSUMER (1976 AVERAGE WAS 2.41)

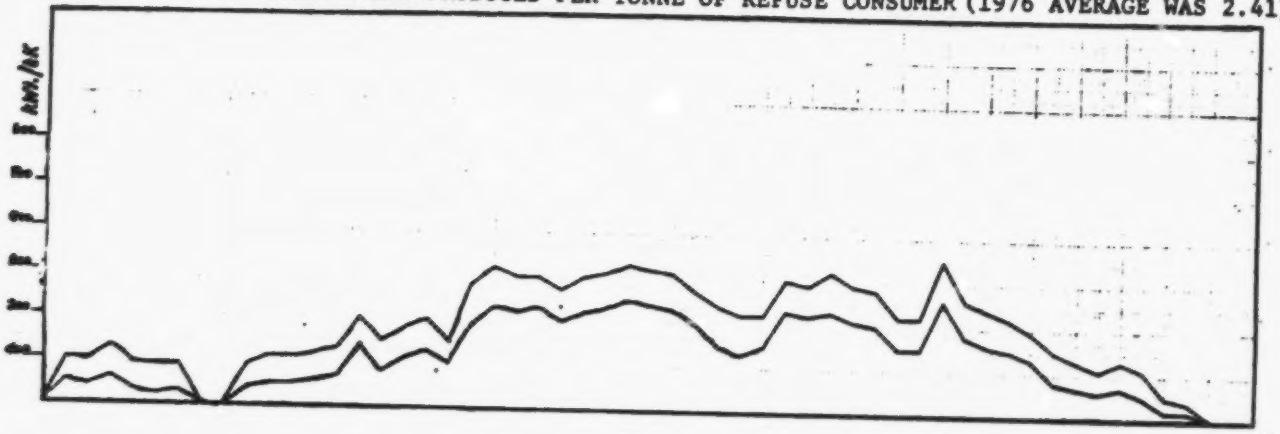


FIGURE 8-26. KWH ELECTRICAL SALES PER TONNE OF REFUSE CONSUMED

Electricity Generation

High temperature/pressure steam from all three Hagenholz units is fed into two Escher-Wyss (since acquired by Sulzer of Zurich) steam extraction-condensing turbines. Each consumes 30 tonnes (33 tons) of steam per hour for a total of 60 tonnes (66 tons).

Each then produces 6 mw for a 12 mw total average 5.25 for a 10.5 mw total) at 11,000 volts which is equal to the local network voltage. Actually there are two electricity customers: the Kanton (local government) and EWZ (a public utility). The turbine speed is 6800 rpm. A large gear box between them connects it to the generator having a 3000 rpm speed. There has been very little trouble with the turbo-generator set. Once produced, the voltage can be lowered to 220 v and 380 v for internal use.

The new Josefstrasse plant will be equipped with two 40 tonne steam per hour Brown-Boveri turbo generator sets. Each will produce 8 mw for a 16 mw total.

District Heating

The Hagenholz refuse fired plant and the nearby oil fired energy plant provide steam and hot water for three different district heating networks. Most of the district heating piping has been in place for many years.

The investor-owned public utility EWZ plant receives hot water from Hagenholz which is added to the larger EWZ supply. This hot water, at 130 C (266 F), is then distributed to many customers in Zurich. The weekly load is shown in Figure 8-27.

The second, a Kanton-owned district heating system, (see the map Figure 8-28) has only a few large customers and has a limited potential as listed below:

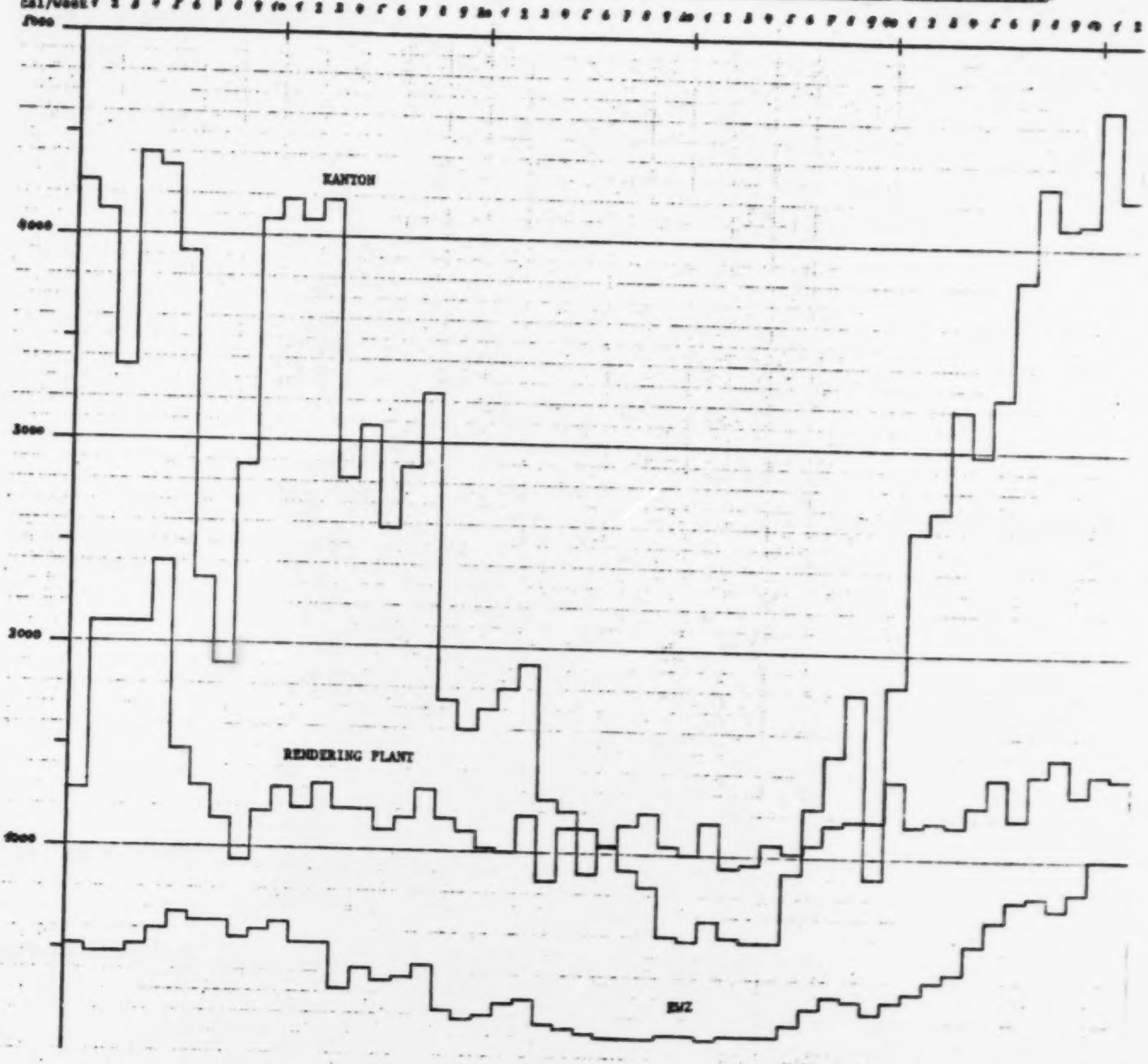
Kanton municipal hospital	(current)
Ramibuhl Factory	(current)
Railroad station	(current)
Post office	(potential)
University	(potential)
Municipal museum	(potential)

This system uses about 15 tonnes (16.5 tons) of steam per hour in the Winter and 10 tonnes (11 tons) per hour in the Summer.

The third district heating system has many apartments and other buildings as customers and is also owned by the Kanton. It is basically the system that the Josefstrasse plant supplied which is now supplied by Hagenholz while Josefstrasse is being rebuilt.

These three district heating networks are supplied by several energy plants. Two of the energy plants are in the Hagenholz suburb; (1) the Hagenholz refuse fired steam generator, and (2) the oil fired energy plant. The supply and return pipelines connecting the two plants with the three networks are in a ground-level, walk-through tunnel covered with earth as shown in Figure 8-29. Figure 8-30 is a cross-section schematic of the tunnel showing the supply and return lines for water, steam, and condensate. This researcher walked about 500 m (1500 feet) into the tunnel with the general overhead plan shown in Figure 8-28.

FIGURE 8-27. 1976 HEAT DELIVERY TO KANTON AND RENDERING PLANT AND STEAM TO EWZ FROM ZURICH: HAGENHOLZ



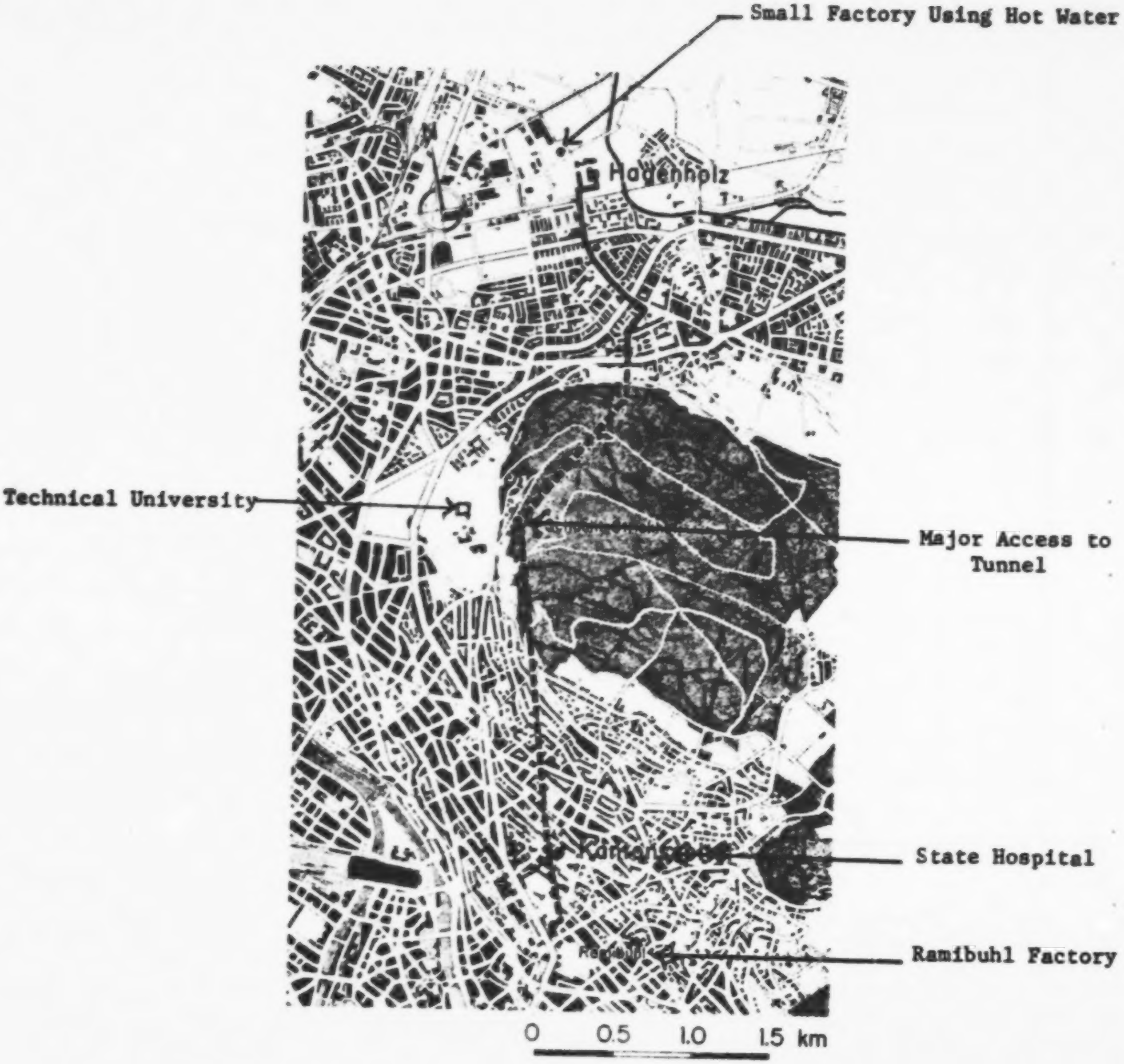

Small Factory Using Hot Water
Hagenholz
Technical University
Major Access to Tunnel
State Hospital
Ramibuhl Factory
0
0.5
1.0
1.5 km

FIGURE 8-28. KANTON DISTRICT HEATING SYSTEM (5.3 km long) USING 260 C (500 F) STEAM AT ZURICH, SWITZERLAND

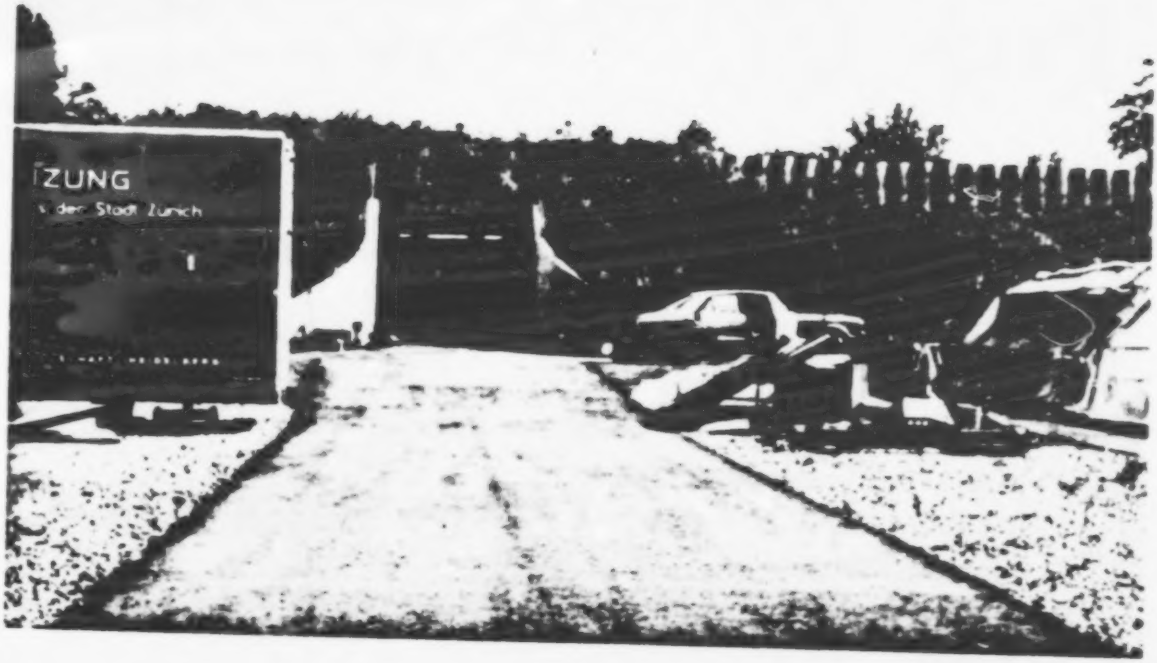
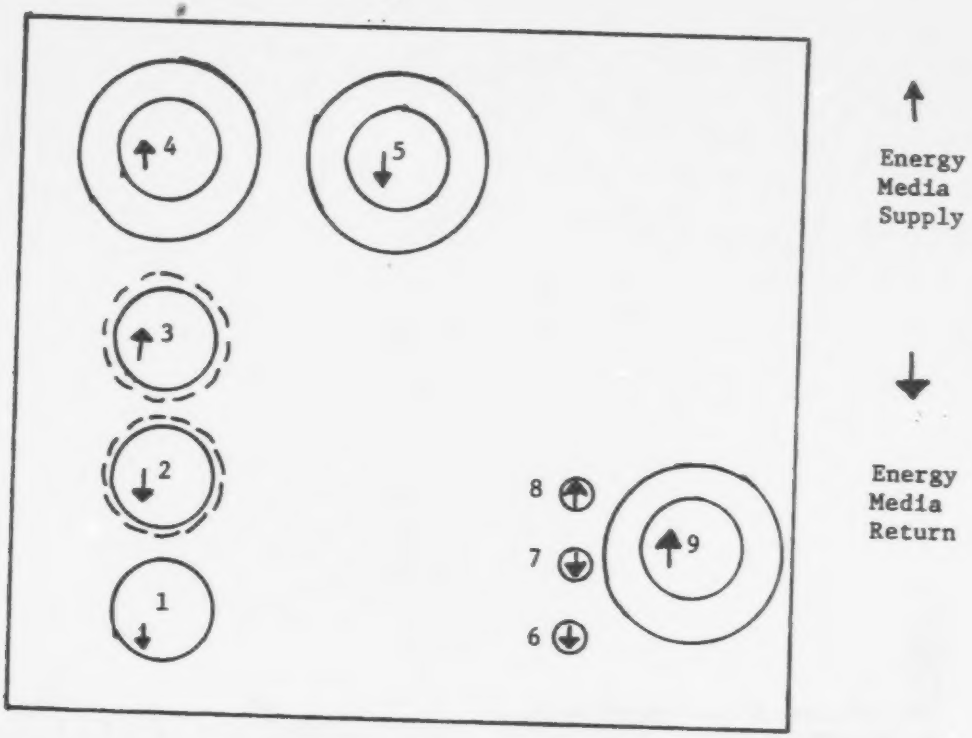

IZUNG
der Stadt Zurich

FIGURE 8-29. ENTRANCE TO WALK-THROUGH DISTRICT HEATING TUNNEL AT ZURICH: HAGENHOLZ



1. Steam condensate return from Kanton district heating network to Hagenholz 70-80 C.
2. Warm water return from Kanton district heating network to new oil energy plant.
3. Hot water supply from oil energy plant to Kanton district heating network for apartments 180 C.
4. Hot water supply from Hagenholz to EWZ plant to EWZ district heating network 130 C.
5. Warm water return from EWZ district heating network to EWZ plant to Hagenholz 100 C.
6. Condensate return from steam purge conditioning tank to Hagenholz (5 atmospheres).
7. Cooling water from City to pump for EWZ plant
8. Total purge condensate return from Kanton district heating network to conditioning tank 200 C (12-14 atmospheres).
9. Steam from Hagenholz to Kanton district heating network 5 km away 260-280 C (12-14 atmospheres).

FIGURE 8-30. CROSS-SECTION SCHEMATIC OF PIPES IN THE DISTRICT HEATING SUPPLY AND RETURN TUNNEL AT ZURICH: HAGENHOLZ

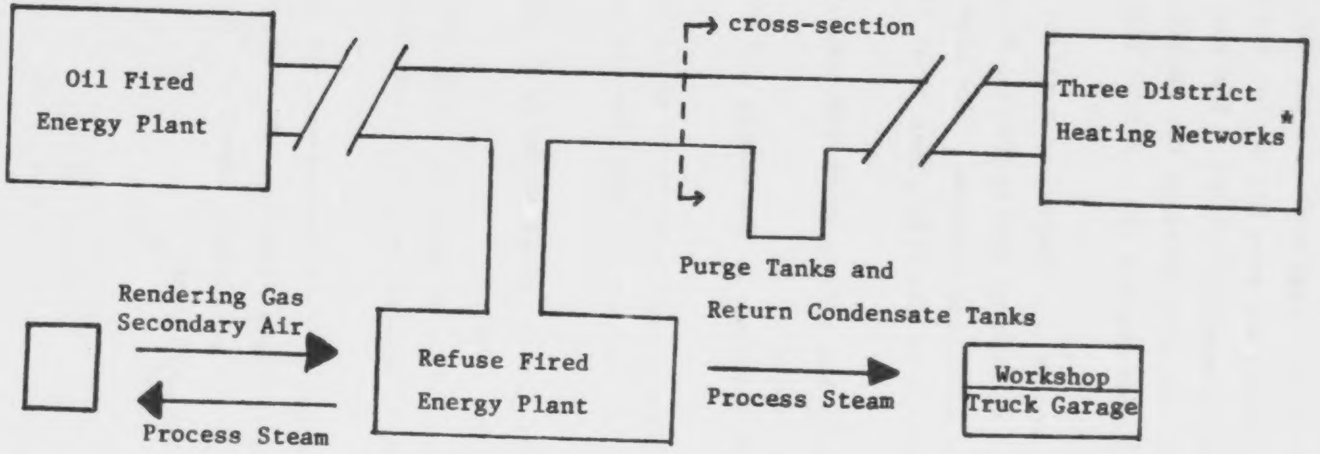

Oil Fired
Energy Plant
cross-section
Three District
Heating Networks*
Purge Tanks and
Return Condensate Tanks
Rendering Gas
Secondary Air
Process Steam
Refuse Fired
Energy Plant
Process Steam
Workshop
Truck Garage

FIGURE 8-31. GENERAL VIEW OF ENERGY DISTRIBUTION FROM ZURICH: HAGENHOLZ

The purge system for outbound steam pipes is used when the steam is being turned off or being turned on. Pipe number 8 travels the distance of the tunnel collecting condensate from the cooled steam pipe (not to be confused with the return condensate pipes). The condensate is collected in the purge tanks and then added to the return condensate tanks. One pipe (number 6) then returns the combined liquid condensate to the Hagenholz plant.

The steam and purge line pressures are limited to a slight superheat of 260 C (500 F) and 12 to 14 atmosphere (175 to 200 psi) because of local regulations relating to pipeline expansion problems. The pipe from the condensate return collection tank back to the RFSG plant is at five atmospheres (73 psi) pressure.

The hot water and steam supply and return lines are inspected and reconditioned once per year in the summer.

The electricity sells for SF 0.06/kwh in the Winter and SF 0.04/kwh in the Summer.

The charge for district heating steam is SF 35 to SF 60/Gcal depending on who the customer is and how much of the pipeline capital cost the customer is paying for.

Figure 8-32 shows the weekly pattern of steam sales to the railroad central station (SBB), KZW and to EQZ.

There has been almost no corrosion of pipes in these walk-through tunnels. The district heating system is stopped once per year for valve repairs where necessary.

There is five to seven percent loss in "refuse-derived condensate" returned to the plant by the district heating networks. However, more H_2O by weight is returned because a disproportionate amount of "oil-derived condensate" is returned to the RFSG plant.

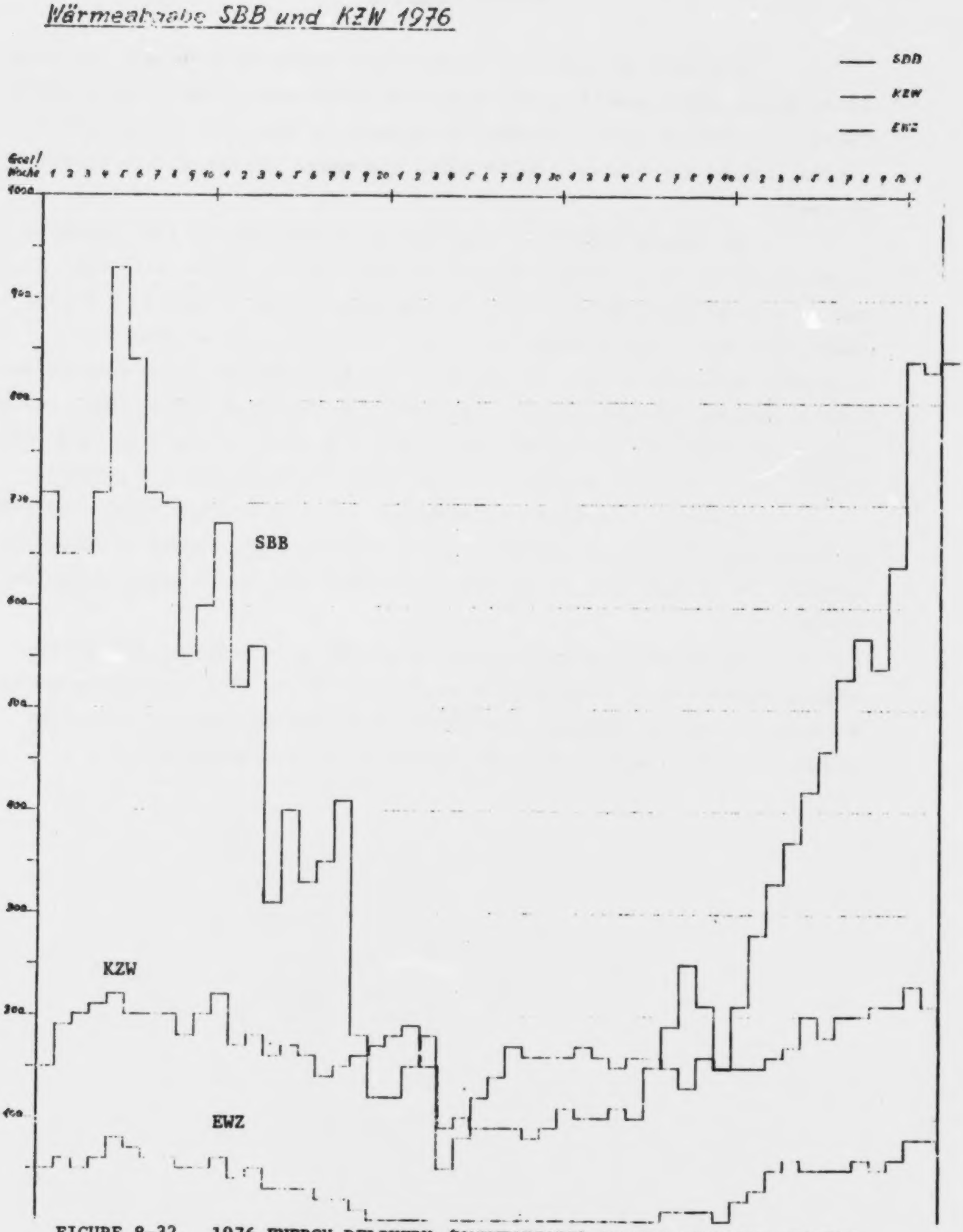


FIGURE 8-32. 1976 ENERGY DELIVERY (WARMEABGABE) TO THE RAILROAD STATION, THE KZW AND EWZ

ENERGY MARKETING

Obtaining new publicly or privately owned large-volume customers is an art or skill practiced by several of Abfuhrwesen's management people. There is no formal plan. However, management is very careful to seek potential customer contacts. Sales calls are made. No fixed rate schedule is used.

The energy plants are operated as profit centers that happen to be owned by the City. Each contract is negotiated. If the City must put in a large pipeline that will be depreciated over 40 years, a higher price will have to be charged for a unit of energy. As an example, Hagenholz sells its steam, at its own plant boundary, at a low rate to the Kanton district heating network. However, Josefstrasse (1904, 1928, and 1979) has always owned and maintained its pipeline network; hence, its rates are higher. To lower the customer's price, quantity discounts are possible.

There are attempts by the Kanton district heating system (Heizamt, a sister organization to Abfuhrwesen) to sell to large apartment complex owners. No attempt is made to encourage individual homeowners to purchase steam.

Officials gave Battelle an eight (8) page contract and financial worksheet as an example of a negotiated offer. This most interesting document between Abfuhrwesen and Migros (the leading food warehouse) is written in German and can be made available to interested parties.

POLLUTION CONTROL EQUIPMENT

Mechanical Collectors

Units #1 and #2 have Rothemuehle multi-cyclone mechanical collectors following the electrostatic precipitators (ESP). However, Unit #3 does not have a mechanical collector. The cyclones were always difficult to clean. The cyclones on the first two units performed well until they were corroded by the high flue gas temperatures. Eventually, the spirals were removed and now the gas flows through the empty cyclone. See the following page for more details.

While Unit #3 does not have a mechanical collector, it does have an open chamber and hopper immediately before the ESP. The larger flue gas cross-sectional area causes some of the heavier particles to fall out, thus reducing the load into the ESP.

Electrostatic Precipitators

Unit #3 has a maximum gas flow rate of 95,580 Nm^3/hour or 26.55 Nm^3/sec assuming that the refuse lower heating value is 2800 kcal/kg (5040 Btu/pound) and that 11,800 kg per hour (13 tons per hour) are combusted. The mean velocity is 0.814 m/sec. The furnace/boiler emits flue gas with 2500 mg/Nm^3 of particulate.

The electrostatic precipitator was manufactured and installed by the Elex organization. It contains two (2) fields and has a crosssecional area of 74.1 m^2 (797 ft^2). The effective surface collection area is 3560 m^2 (38,306 ft^2).

Elex felt that it had enough experience and a flow-model study was not performed. Mr. Erick Moser, the technical assistant lamented that, "There is never enough information on (inlet) gas and dust composition."

Flue gases must pass through a perforated plate and a series of baffles before entering the electric field. The output voltage is 78 kv with an effective output current of 2,430 ma.

The unit is cleaned by mechanical rapping with a hammer. Flyash falls through pyramidal hoppers and is removed by a feedscrew.

The insulation is 80 mm (3.1 in) thick. In the Winter, the hopper is electrically heated.

The flue gas temperature entering the ESP is usually 280 C (536 F). See the previous Table 8-10. If it rises to above 300 C (572 F), there is serious danger of high temperature corrosion from Zinc Chloride deposits. The chemical attacks the steel until it becomes spongy and short circuits become common.

Plant staff cautioned about closing the plant every weekend. They have observed other plants that develop dew point corrosion at the 150 C (302 F) flue gas temperature level. When the unit is shut down eight (8) hours for the 1000 hour planned inspection, the ESP is kept warm by the 150 C (342 F) steam from the (Number 2 fuel oil or waste oil) boiler. The ESP is thus cooled only twice per year - during the 4000 hour planned inspections.

Whenever the ESP falls below 78 kv and cannot maintain a 65 kv charge across the fields, then operators know the excessive short circuiting is occuring and that inspection and maintenance should soon follow.

When Units #1 and #2 were built, the Swiss air pollution law limited emissions to 150 mg/Nm^3 corrected to 7 percent CO_2. The Zurich request for proposals (RFP) specified a 100 mg/Nm^3 limit. The two-field Elex ESP followed by the Rothemuehle multi-cyclone more than met the requirements and average 70-90 mg/Nm^3 during compliance tests. Later, after the units had been operating over the critical 300 C (572 F) limit, corrosion began and later readings changed to 120 mg/Nm^2. The original compliance test for one of the first units produced the following:

	Units #1 and #2	
Particulates - total	72 mg/Nm^3	(currently about 120 mg/Nm^3)
Particulates - over 30 u*	15 mg/Nm^3	
CO_2	7.7%	
O_2	9.2%	
H_2O (or H_2)	15.7%	
SO_2	219 mg/Nm^3	
HCl	531 mg/Nm^3	

When Unit #3 was built, the regulation had been tightened to 100 mg/Nm^3 for particulates. The RFP thus specified 75 mg/Nm^3. During the compliance test, conducted by EMPA, an excellent reading of 42 mg/Nm^3 was recorded as well as these other figures. Assuming an inlet loading of 2500 mg/Nm^3 and an output reading of 42 mg/Nm^3 means that the unit operates at 98.3 percent efficiency.

Unit #3	
Particulates - total	42 mg/Nm^3
CO_2	8.4%
H_2O	12.0%
SO_2	220 mg/Nm^3
HCl	840 mg/Nm^3
HF	11 mg/Nm^3
ZnO	4.7 mg/Nm^3
Pb	0.37 mg/Nm^3

Now that the third generation Josefstrasse is being built (Martin is the designer), the RFP specification has been tightened further to 50 mg/Nm^3. As of this writing, the plant is under construction and thus no compliance test has been made. Officials have been so pleased with the Elex precipitator (marketed by American Air Filter in the U.S.), that it was easily chosen for Hagenholz.

The Federal Switzerland Government had a financial incentive program several years ago that motivated construction of many refuse fired steam generators. A condition for the Federal money was that the plant pass its compliance test. Prior to passing the test, vendors would have to wait for their money or the city would have to obtain a short term bank loan. As compared to several other countries, this policy has done much to ensure plants with well controlled emissions.

This program still exists on paper, but funds have not been nearly as plentiful as in years before. In many Swiss regions there has been overbuilding of these plants and several persons have mentioned that Switzerland is "saturated" with RFSG's.

Stack Construction

The single Hagenholz chimney is a single flue brick-lined stack 91 m (300 feet) tall with a top inside diameter of 3.8 m (12 feet). Inspections are made twice per year. So far (since 1969), there have been no chimney repairs. However, a galvanized ladder has exhibited some corrosion. The chimney is expected to last 20 to 70 years. The original 1904 Josefstrasse stack was used for 70 years.

Unfortunately, with three furnaces supplying flue gas to a single flue chimney, the flue gas velocity may be reduced by 1/3 or 2/3 depending on how many units are in operation. Therefore, the new Josefstrasse will have a three flue steel-lined chimney. Since each furnace will have its own flue, flue gas velocity will thus be independent of how many furnaces are operating, i.e. the plume will generally behave as is desired. Another feature of Josefstrasse is that when upper sections become corroded, a ground level hydraulic system can raise all other sections. The deteriorated top section can be removed and another new steel section, 5 m (16 feet) long can be inserted at the bottom.

Fly Ash

To prevent blowing dust from flyash, it needs to be wetted. This is most difficult in the Summer and with freezing, almost impossible in the Winter. As a result, the screw conveyors transport all flyash to the ash discharger where it is inserted 1 m (3 feet) above the water level. Some dust is recycled through the furnace/boiler/ESP but that is no real problem. The flyash and bottom ash are later recycled for roadbuilding.

Waste Water Discharge

Generally speaking, the higher the refuse calorific content, the less amount of water per hour is needed to operate the system. Hence, there is less waste water. The following demonstrates assuming a heat release rate of 33,000 Gcal/hr:

Lower Heating Value (kcal/kg)	1800	2400	3000
Waste Water (liter/hour)	1500	1200	900
Waste Water (Gallons/hour)	396	317	238

Hagenholz waste is around 2100 to 2200 kcal/kg so about 1350 liters per hour is added to the ash quencher. There is no overflow of water from the quench tank to the sewer. Only toilet waste water and used boiler blowdown water are put in the sewer.

Noise

During the day, noise must be kept under 45 decibels at distances further than 100 m (328 feet) from the plant fences. At night, after 8:00 p.m., the turbine windows must be closed to abate noise.

Air Cooled Steam Condensers

Large vertical louvers, made by GEA of Bochum, West Germany, are installed on the roof wall around the air-cooled steam condenser fan bottoms to abate noise.

Separately, the V-belt drive on the condenser fans started squealing at low speeds. They now have two-speed motors.

The condensing capacity is 75 tonnes (82.5 tons) per hour. At present they condense about 40 tonnes (44 tons) per hour from the extraction condensing turbines.

Previously, Hagenholz had freezing problems in the Winter. They now feed steam first to what would otherwise be the coldest part of the condenser.

Figure 8-33 shows the cooling tower.

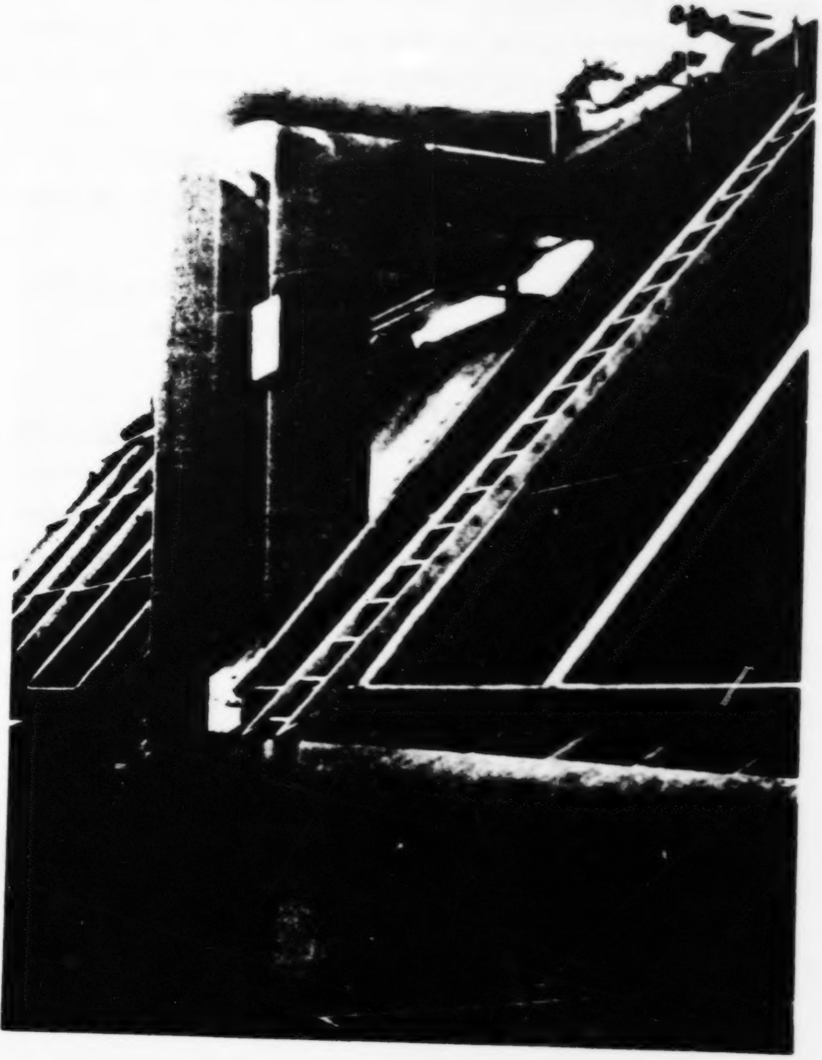


FIGURE 8-33. COOLING TOWER AT HAGENHOLZ (Battelle Photograph)

ASH RECOVERY

Ash recovery is very advanced at Hagenholz. Credit for this accomplishment is to be shared among several parties that have funded and guided the research and development. The entire program is outlined in an excellent 50-page report written by Professor R. Hirt, a professor of forest engineering at the Technical University in Zurich. His publication is titled, "Die Verwendung von Kehrichtschlacke als Baustoff fuer den Strassenbav", dated October, 1975. The German title translated is "Use of Processed Incinerator Ash for Road Building". The report is available through Mr. Hirt or Battelle.

The analysis mentions many Swiss cities. But for the City of Zurich alone the following general 1974 data are presented:

	City of Zurich	14 Large Swiss Cities
Population	421,650	2,314,100 people
Refuse (generated)	216,000	812,485 tonnes/year
Refuse per person (kg basis)	512	351 kg/person/year
Refuse per person (pounds basis)	1,126	772 pounds/person/year
Refuse per person (365 days basis)	3.08	2.12 pounds/per day
Ash generated by incinerators*	61,800	271,260 tonnes/year
Ash per person (kg basis)	147	117 kg/person/year
Ash per person (pounds basis)	323	257 pounds/person/year
Ash per person (365 days basis)	0.88	0.70 pounds/person/day
Ash as % of Refuse	28.6	33.4 tonnes/tonnes

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* Josefstrasse and Hagenholz both in 1974.

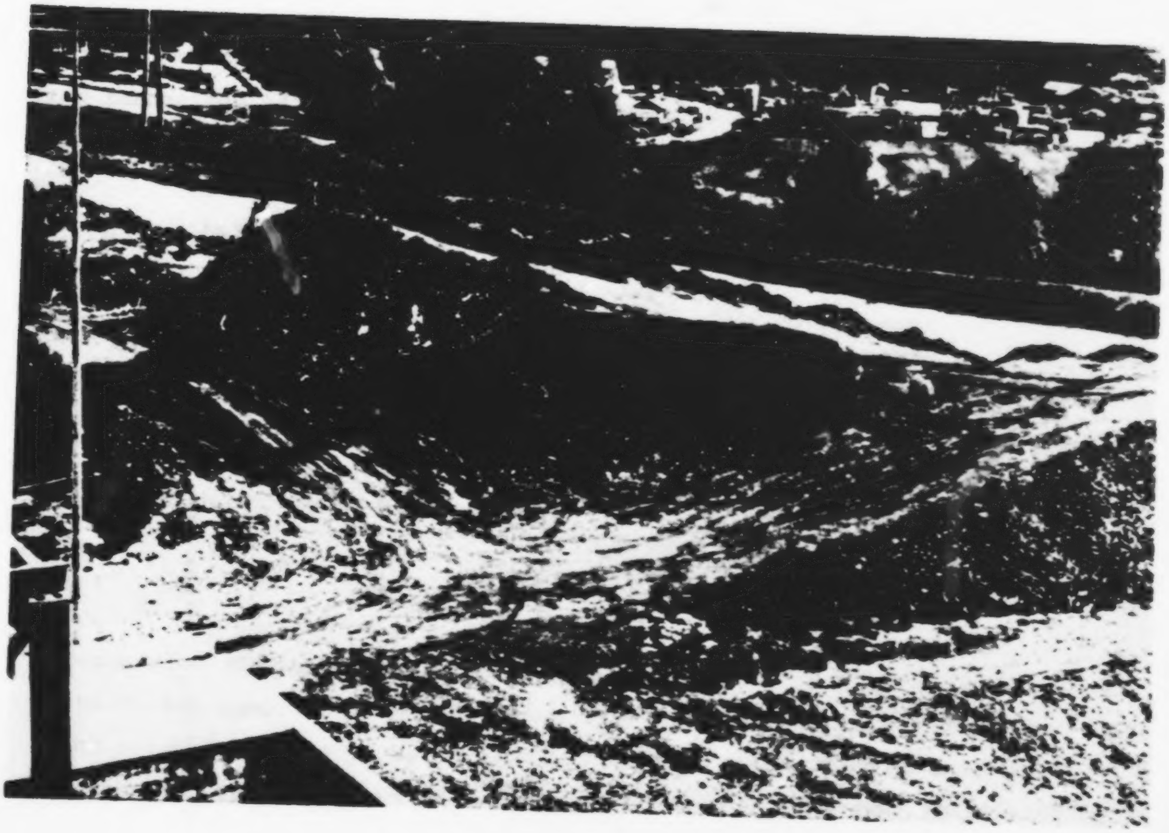

FIGURE 8-34. PARTIALLY PROCESSED RESIDUE AT HAGENHOLZ (Battelle Photo)

The ash residue (slag), when removed from the ash bunker, is stored in a pile for two months for these several reasons:

- moisture reduction
- stop fires
- chemical reactions
  - heat hydration of free lime
  - water and calcium carbonate

These exothermic reactions result in an internal temperature of 80 C (176 F). The bottom ash and flyash combined residue has a Ph of 11 or 12. Interestingly, the dirty water removed during the semiannual boiler cleaning to remove flyash deposits has a Ph of 2 or 3--an alkali is the cleaning agent.

In 1976, the actual following figures were reported:

Quantity of solid waste burned	218,342 tonnes	100.0%
Quantity of raw ash generated	56,271 tonnes	25.8%
Quantity of metal recovered	6,494 tonnes	3.05

The following are percentage ranges for output from the ash recovery process:

Roadbuilding material	80%	
Ferrous metals	8-9%	(before recession 10-12%)
Non-ferrous mediums returned to furnace	3-5%	
Stumps and tires sent to landfill	3-5%	

Except for uncaptured particulates and gases, the only materials leaving the plant in an unrecycled mode are the tree stumps and tires. This amounts to 3 to 5% of ash and ash is 25.8% of the total waste input. This means that 98.75 to 99.25% is the volume reduction for purposes of calculating necessary landfill requirements.

The copper is manually pulled out and sold as scrap when conveniently seen and removable. Aluminum is recycled indefinitely until oxidized.

In 1974, before the recession, ferrous incinerator scrap sold for SF 30-90 per tonne depending on the season and strikes in Italy and France. In 1977, the price range from SF 30-35 per tonne F.O.B. Zurich.

The roadbuilding ash (or slag as most Europeans call it) sells for 10% under the competitive price for gravel. Mr. Hirt believes that the long term price is bound to rise substantially as gravel pits become scarce. The 1974 price of SF 12 had fallen to SF 6 in 1977 due to the recession.

Most of the slag is used for secondary roads. They can operate in rain and freezing weather due to the exothermic reactions.

There is a new plant that is planned to mix the material as aggregate with cement to serve the Zurich and Winterthur areas.

Because the material can also be used as road base for paved roads, several tests have been conducted. Tubes made of PVC, cement, zinc, rubber, etc. have been inbedded in the processed ash to determine corrosion effects.

Three people, not employees of Abfuhrwesen, operate the facility for a joint venture owned by the Bless and the Muldenzentrale companies.

Figure 8-35 through 8-42 show the various stages of residue processing.

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FIGURE 8-35. SEGREGATED BULKY RESIDUE FROM FURNACE AT HAGENHOLZ
(Battelle Photograph)

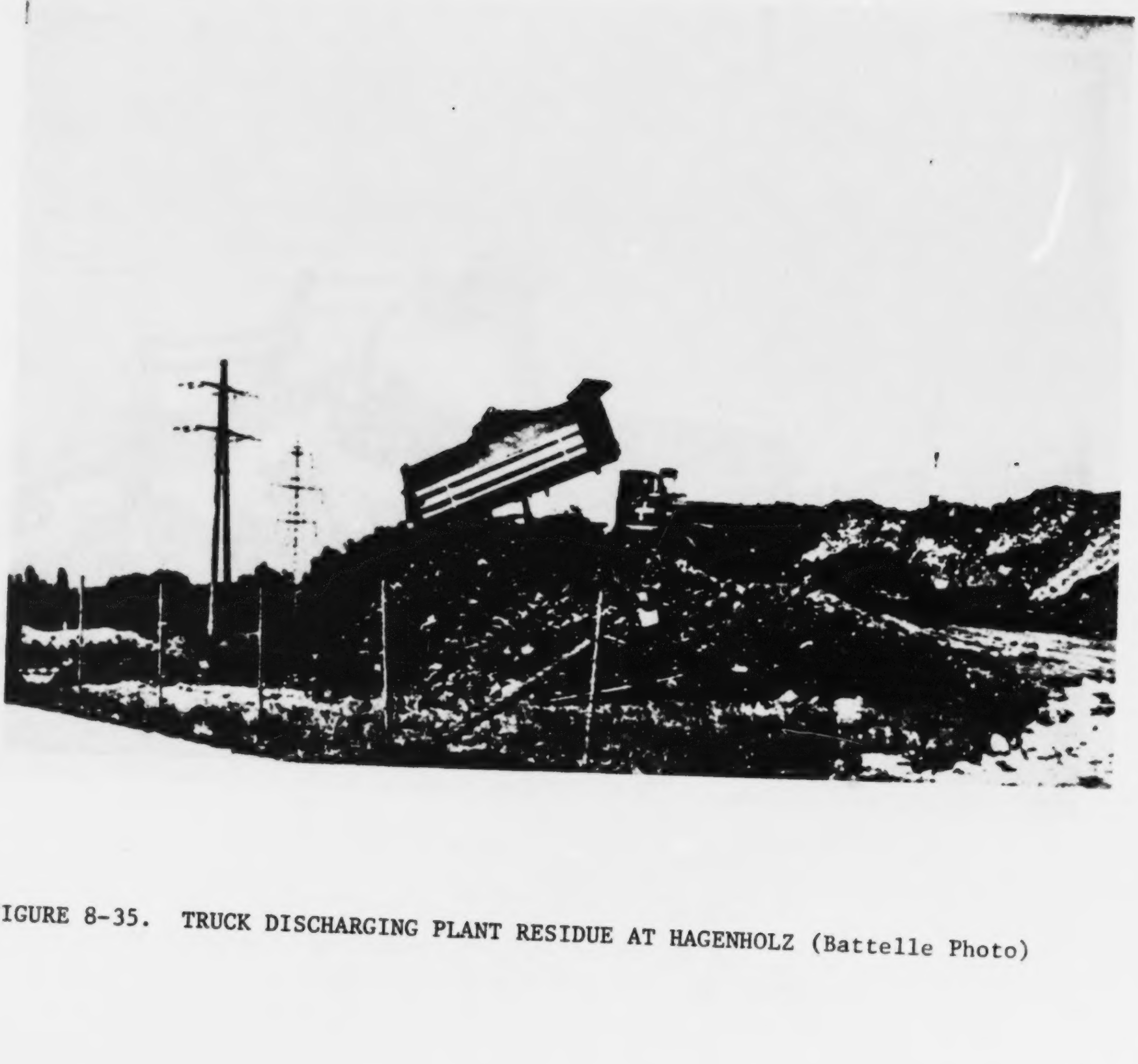

FIGURE 8-35. TRUCK DISCHARGING PLANT RESIDUE AT HAGENHOLZ (Battelle Photo)

FIGURE 8-37. FRONT-END LOADER DELIVERING RESIDUE TO HAGENHOLZ PROCESSING SYSTEM (Battelle Photograph)

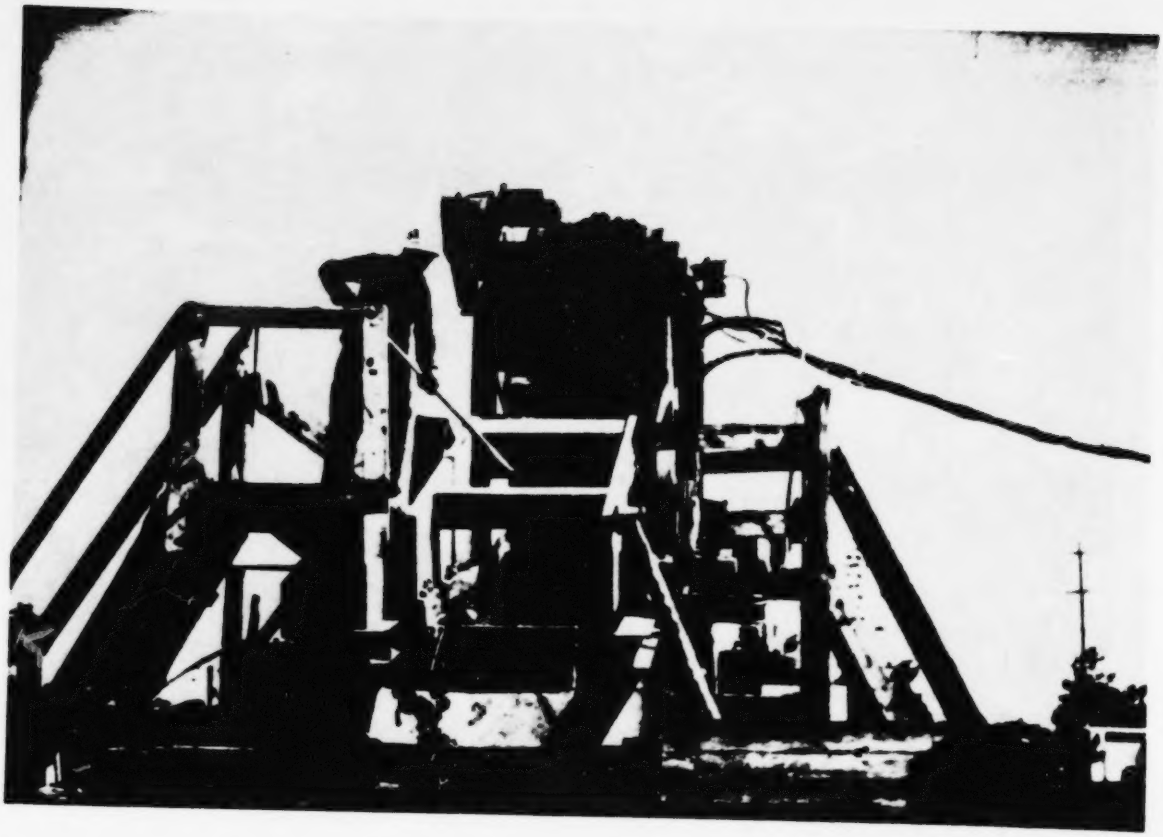

FIGURE 8-38. WORKER REMOVING WIRE FROM WASTE PROCESSING CONVEYOR AT HAGENHOLZ (Battelle Photograph)

FIGURE 8-39. SMALL SIZE METAL FROM HAGENHOLZ RESIDUE-PROCESSING PLANT (Battelle Photograph)

FIGURE 8-40. MEDIUM AND LARGE METALLICS FROM HAGENHOLZ RESIDUE-PROCESSING PLANT (Battelle Photograph

FIGURE 8-41. NON-FERROUS SIZED RESIDUE FOR ROADBUILDING AT HAGENHOLZ (Battelle Photograph)

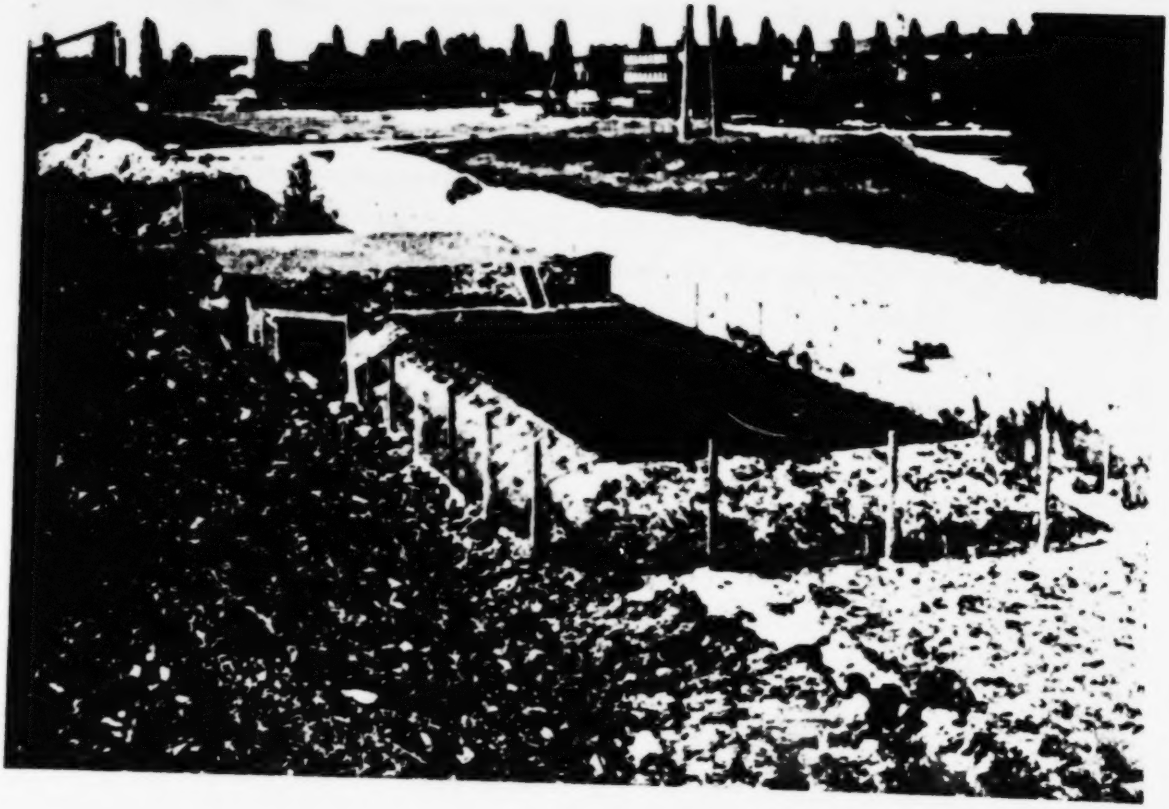

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FIGURE 8-2. TEST SLABS AT HAGENHOLZ CONTAINING SIZED RESIDUE
(Battelle Photograph)

PERSONNEL AND MANAGEMENT

Figure 8-43 displays the City of Zurich's organization. The Hagenholz plant itself is part of the Abfuhrwesen (Waste Disposal Organization) which reports to Gesundheits - und Wirtschaflsamt (Health and Cleansing Department). Note that the Heizamt (City's heating organization) and the Elekrizitatswerk (electric works) are each in different departments. This makes more impressive the attitude of Max Baltensperger, Chief of the Waste Disposal Organization, that the Hagenholz RFSG is primarily an energy facility and secondarily a waste disposal facility.

The waste collection, Hagenholz, Josefstrasse, and rendering plant relationships are shown in the Abfuhrwesen organization chart: Figure 8-44. The activities above the dash line are performed at City Hall.

Compared to other European RFSG plants, the plant level organization chart is less precise. There are no shift specialists. Each man gets to do all the jobs around the plant. The philosophy is that the men should take more interest in the overall plant operation. Changing assignments also tend to inhibit formation of cliques and selfish attitudes.

Each of the 39 men work a 44 hour week. There are four operators per shift as follows: shift foreman, crane operator, maintenance man, and control room operator. Service contracts with outside firms permit a limited staff size.

Each supervisory and management person in the plant must submit a written report weekly to his supervisor. This includes Max Baltensperger's report to the nine (9) member Council.

While the plant staff has walkie talkies, they are seldom used. The crane operators and the control room operators frequently talk by telephone.

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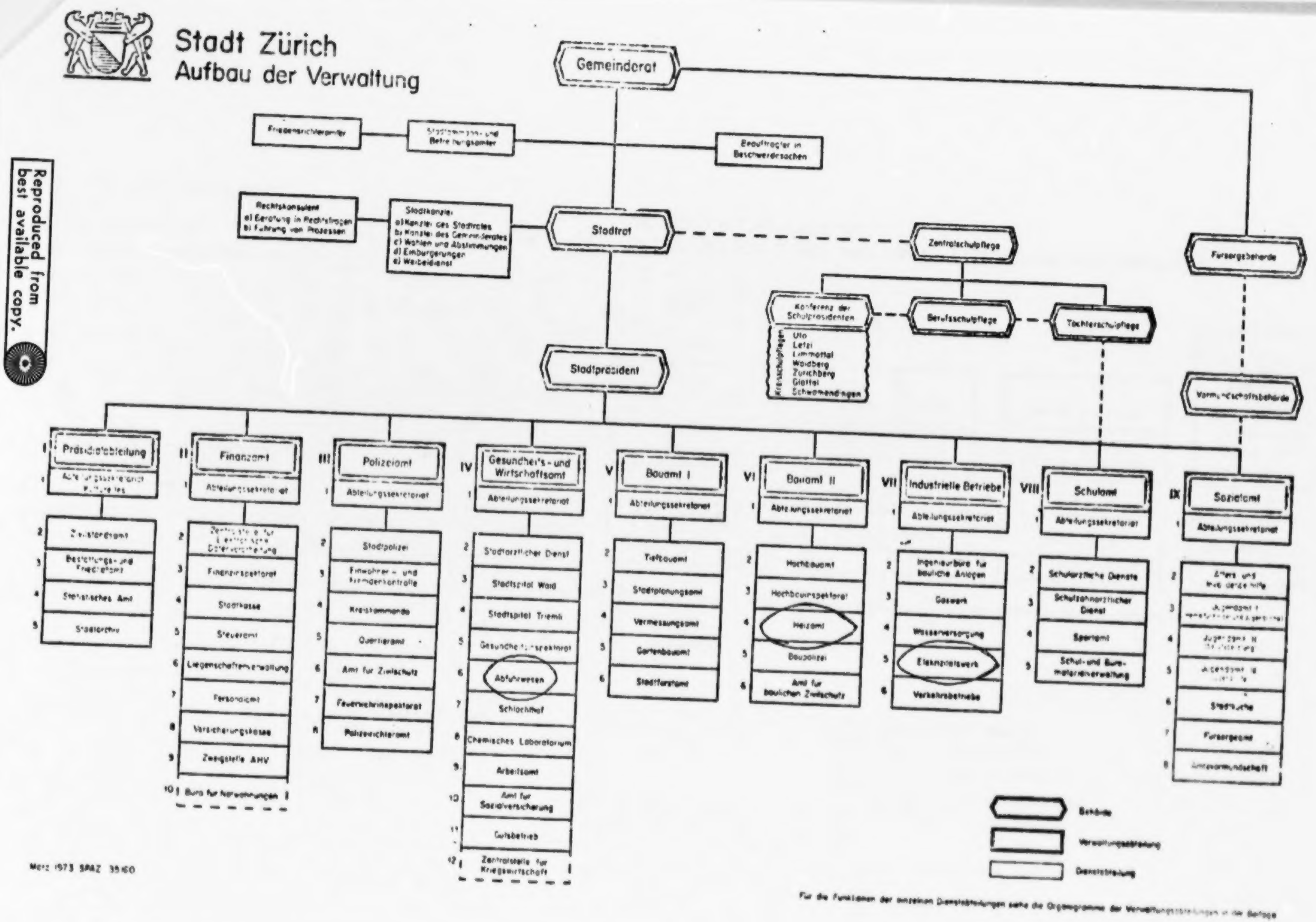
Stadt Zürich
Aufbau der Verwaltung
Gemeinderat
Friedensrichterämter
Stadtammann- und Betreibungsämter
Beauftragter in Beschwerdesachen
Rechtskonsulent
a) Beratung in Rechtsfragen
b) Führung von Prozessen
Stadtkanzlei
a) Kanzlei des Stadtrates
b) Kanzlei des Gemeinderates
c) Wahlen und Abstimmungen
d) Einbürgerungen
e) Weibeldienst
Stadtrat
Stadtpräsident
Zentralschulpflege
Konferenz der Schulpräsidenten
Kreisschulpflegen
Uto
Letzi
Limmattal
Waidberg
Zürichberg
Glattal
Schwamendingen
Berufsschulpflege
Töchterschulpflege
Fürsorgebehörde
Vormundschaftsbehörde
I Präsidialabteilung
1 Abteilungssekretariat Kulturelles
2 Zivilstandsamt
3 Bestattungs- und Friedhofamt
4 Statistisches Amt
5 Stadtarchiv
II Finanzamt
1 Abteilungssekretariat
2 Zentralstelle für Elektronische Datenverarbeitung
3 Finanzinspektorat
4 Stadtkasse
5 Steueramt
6 Liegenschaftenverwaltung
7 Personalamt
8 Versicherungskasse
9 Zweigstelle AHV
10 Büro für Notwohnungen
III Polizeiamt
1 Abteilungssekretariat
2 Stadtpolizei
3 Einwohner- und Fremdenkontrolle
4 Kreiskommando
5 Quartieramt
6 Amt für Zivilschutz
7 Feuerwehrinspektorat
8 Polizeirichteramt
IV Gesundheits- und Wirtschaftsamt
1 Abteilungssekretariat
2 Stadtärztlicher Dienst
3 Stadtspital Waid
4 Stadtspital Triemli
5 Gesundheitsinspektorat
6 Abfuhrwesen
7 Schlachthof
8 Chemisches Laboratorium
9 Arbeitsamt
10 Amt für Sozialversicherung
11 Gutsbetrieb
12 Zentralstelle für Kriegswirtschaft
V Bauamt I
1 Abteilungssekretariat
2 Tiefbauamt
3 Stadtplanungsamt
4 Vermessungsamt
5 Gartenbauamt
6 Stadtforstamt
VI Bauamt II
1 Abteilungssekretariat
2 Hochbauamt
3 Hochbauinspektorat
4 Heizamt
5 Baupolizei
6 Amt für baulichen Zivilschutz
VII Industrielle Betriebe
1 Abteilungssekretariat
2 Ingenieurbüro für bauliche Anlagen
3 Gaswerk
4 Wasserversorgung
5 Elektrizitätswerk
6 Verkehrsbetriebe
VIII Schulamt
1 Abteilungssekretariat
2 Schulärztliche Dienste
3 Schulzahnärztlicher Dienst
4 Sportamt
5 Schul- und Büromaterialverwaltung
IX Sozialamt
1 Abteilungssekretariat
2 Alters- und Invalidenhilfe
3 Jugendamt I
4 Jugendamt II
5 Jugendamt III
6 Stadtküche
7 Fürsorgeamt
8 Amtsvormundschaft
Behörde
Verwaltungsabteilung
Dienstabteilung
Für die Funktionen der einzelnen Dienstabteilungen siehe die Organigramme der Verwaltungsabteilungen in der Beilage
März 1973 SPAZ 35160

FIGURE 8-43. ORGANIZATION CHART FOR MUNICIPAL FUNCTIONS IN THE CITY OF ZURICH: SWITZERLAND

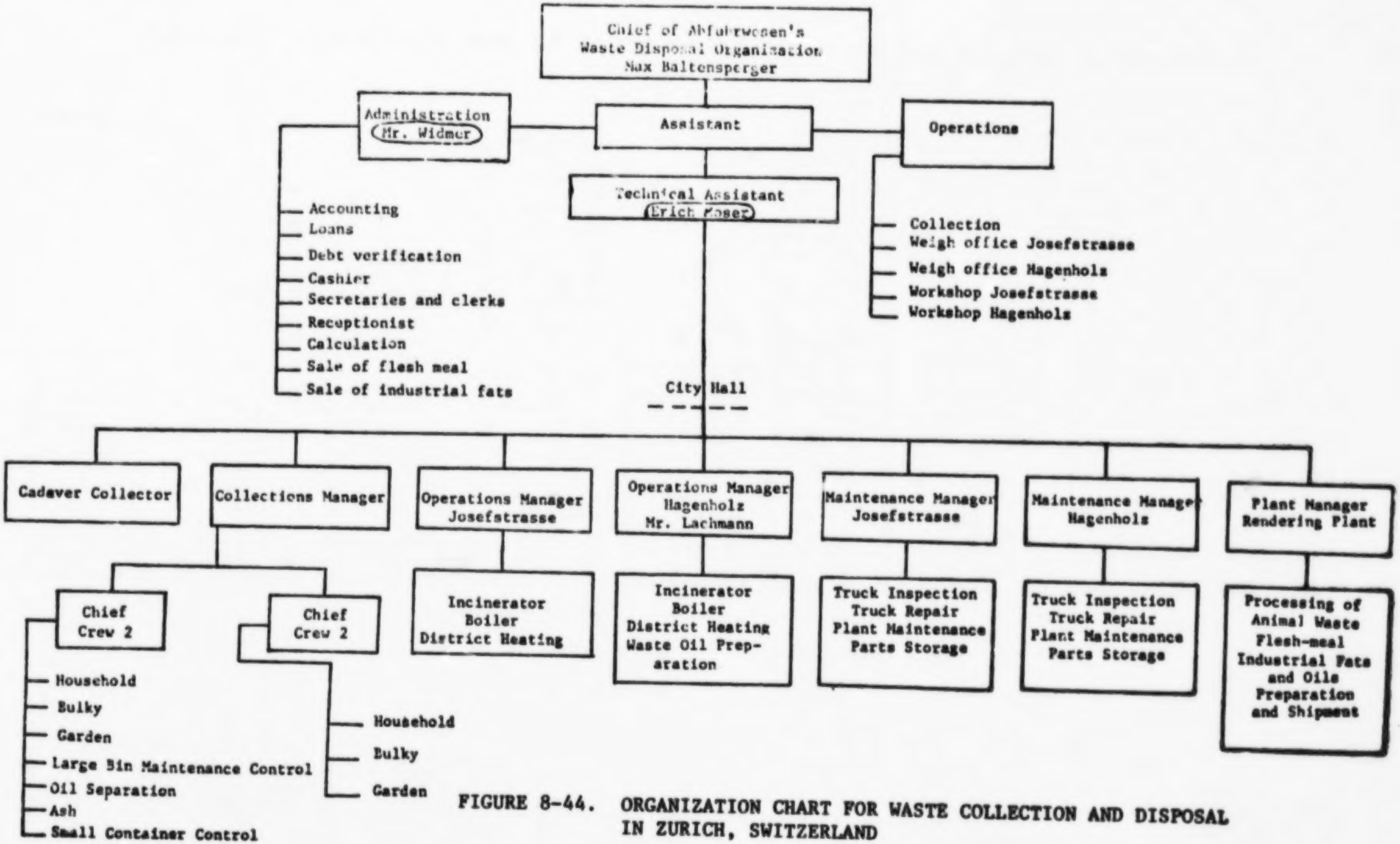
Chief of Abfuhrwesen's
Waste Disposal Organization
Max Baltensperger
Administration
Mr. Widmer
Assistant
Operations
Technical Assistant
Erich Moser
Accounting
Loans
Debt verification
Cashier
Secretaries and clerks
Receptionist
Calculation
Sale of flesh meal
Sale of industrial fats
Collection
Weigh office Josefstrasse
Weigh office Hagenholz
Workshop Josefstrasse
Workshop Hagenholz
City Hall
Cadaver Collector
Collections Manager
Operations Manager Josefstrasse
Operations Manager Hagenholz Mr. Lachmann
Maintenance Manager Josefstrasse
Maintenance Manager Hagenholz
Plant Manager Rendering Plant
Chief Crew 2
Chief Crew 2
Incinerator Boiler District Heating
Incinerator Boiler District Heating Waste Oil Preparation
Truck Inspection Truck Repair Plant Maintenance Parts Storage
Truck Inspection Truck Repair Plant Maintenance Parts Storage
Processing of Animal Waste Flesh-meal Industrial Fats and Oils Preparation and Shipment
Household
Bulky
Garden
Large Bin Maintenance Control
Oil Separation
Ash
Small Container Control
Household
Bulky
Garden

FIGURE 8-44. ORGANIZATION CHART FOR WASTE COLLECTION AND DISPOSAL IN ZURICH, SWITZERLAND

Switzerland, being a landlocked nation, does not have as many former seamen running their boilers. Instead, some of the people come from industry such as Brown Boveri, Sulzer, etc. Often a young man will start as an apprentice machinist or pipefitter. Training is primarily on the job as compared with the rigorous schooling/experience program in Germany. Accordingly, promotion is based on merit and actual contribution to the plant operations and not based on formal progression through a schooling/experience program.

The total number of personnel (collection, disposal, administration, rendering plant, etc.) since 1911 is shown in Figure 8-35.

Plant staff stated that the change from garbage cans to paper and plastic bags greatly reduced the manpower requirements for collectors. The third reason for keeping manpower levels low, costs low, and efficiency high, is the bonus. In 1976, management shared SF 2,737 while the plant people shared SF 17,617. A fourth reason is that 50% of the people are in the local union.

Start-up Procedure

The Number 2 fuel oil boiler produces 150 C (342 F) steam that is put into the boiler. This helps eliminate dew point corrosion. Steam from this oil boiler is also used to heat tubes in the air preheater, also to 150 C (342 F). The electrostatic precipitator is turned on after about 1/2 hour. Whenever they shut-down for the 1000 hour checks, the ESP is kept hot.

At one point, a comparison was made between Hamburg: Stellinger Moor and Zurich: Hagenholz--both plants operated by municipal governments. The main difference was that the Stellinger-Moor is causually operated as a well run municipal department. Hagenholz, however, leanly and efficiently, is operated as if it were private energy-generating enterprise. At Hamburg, the primary objective is clean disposal of waste.

1/2-hour. After about 1-1/2 hours, fairly dry and high calorific value waste is fed into the furnace and the charge is lit.

When the unit is stopped for its 1000 hour inspection, the ESP is kept hot to prevent dew point corrosion.

Amount of Staff from 1911

Abfuhrwesen

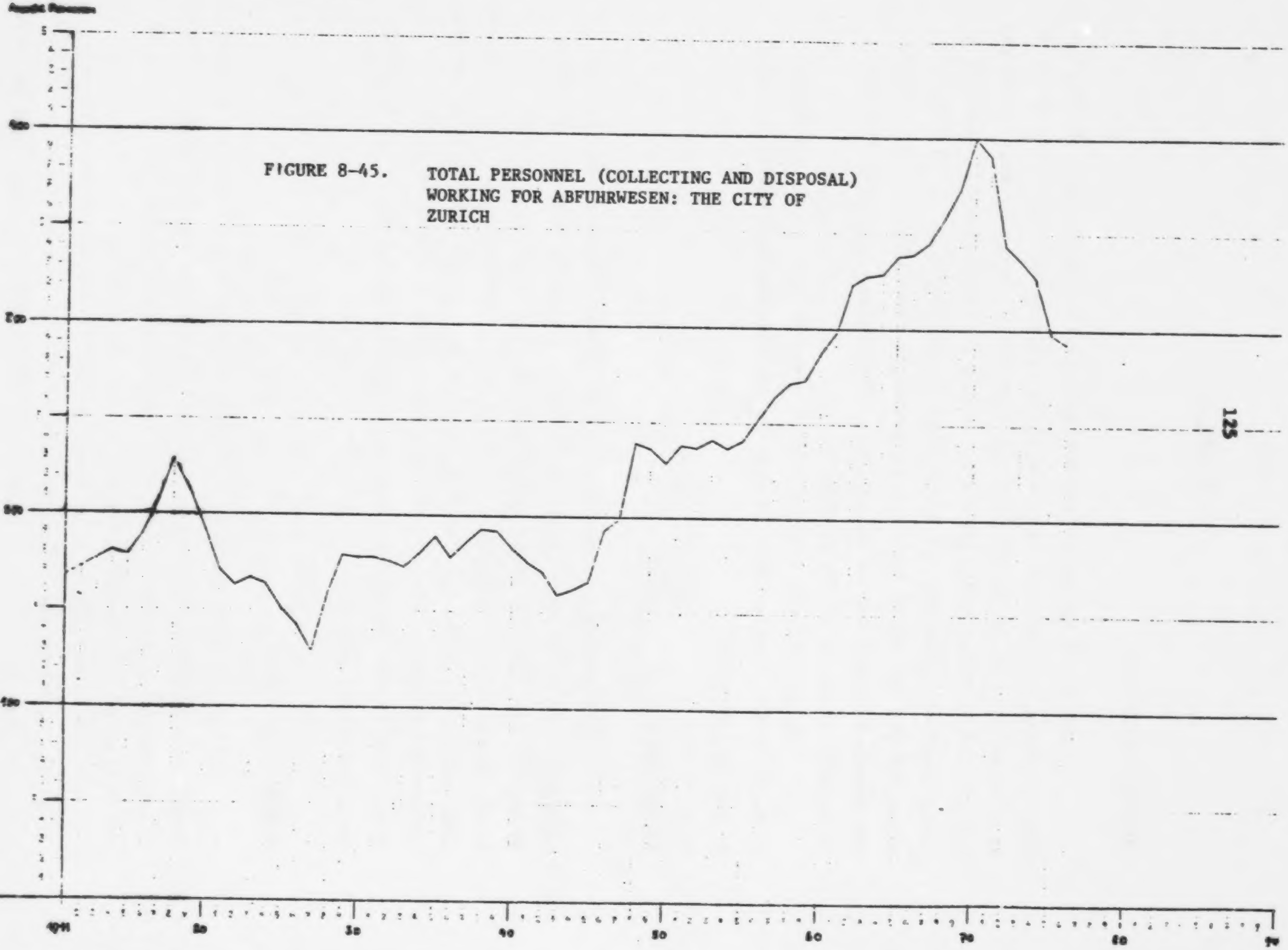

FIGURE 8-45. TOTAL PERSONNEL (COLLECTING AND DISPOSAL) WORKING FOR ABFUHRWESEN: THE CITY OF ZURICH

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ECONOMICS

Capital Investment

The first two units and the administration, social, truck repair, truck storage, bicycle storage, and space parts areas were built in 1969 at a total cost of SF 56,000,000. Of this total, about SF 45,694,000 was for the refuse fired steam generator (RFSG) building itself. Von Roll's chute-to-stack price was SF 23,000,000. Later, in 1973, an additional SF 14,000,000 was spent for Unit #3 and water deaeration. Out of this, the Martin contract was SF 11,430,000. This brings the total for all three RFSG units to SF 59,700,000.

Details of the first Von Roll construction period are shown in Table 8- 8 . Similar details for the last Martin construction period follow in Table 8-9 .

Annual Costs

A separation of annual costs to operate Units #1 and #2 from operation costs for Unit #3 is impossible. Annual 1976 costs, totaling SF 14,414,893, include costs of operations, maintenance, interest, and other costs, and are portrayed in Table 8-11. The costs are for all three RFSG units. Excluded are costs to inspect and repair the fleet of garbage collection trucks. The cost pattern since 1928 is shown in Figure 8-36. Notice the excellent control over salaries and wages and hence the total personnel costs.

Annual Revenues

Annual 1976 revenues, totaling SF 14,424,262, include tipping fees; sale of steam, hot water, electricity and ferrous; a large insurance settlement for a turbine, rent of a tire shredder, credit for repairs to other City of Zurich vehicles, and other incomes.

Dividing the tipping fee, charged to non-Abfuhrwesen trucks, of SF 2,210,966 by the annual tonnage of 94,000 tonnes, yields a SF 23.46/tonne tipping fee. However, the public tipping fee charged, and the subsidy later paid total of SF 5,417,988, divided by 121,559 tonnes, yields a public Abfuhrwesen collection tipping fee per ton of SF 44.57/tonne.

TABLE 8-8. CAPITAL INVESTMENT COST (1969) FOR UNITS #1 AND #2 AND OTHER BUILDINGS AT ZURICH: HAGENHOLZ

	Total Complex (SF)	RFSG Only (SF)
Building costs (excavation, foundation, structure, stack,...)	11,000,000	11,000,000
Equipment (Von Roll contract chute to stack) (boiler, furnace,...)	23,000,000	23,000,000
Outfit	20,000	20,000
Administrative building	2,500,000	1,250,000
Workshop	2,200,000	440,000
Trucks-garage	700,000	--
Connection-way (alley)	1,200,000	--
Scale house	350,000	350,000
Bicycle house	100,000	50,000
Grading	750,000	375,000
Environment (garden, fences,...)	600,000	300,000
Streets and parking places	1,300,000	650,000
Oil storage tank	115,000	115,000
Others		
Land*		
Construction management fee		
Engineering fees		
Interest during construction		
Others Total	12,000,000	8,144,000
Capital Investment	59,700,000	45,694,000

*(SF 6,000,000 value of land previously purchased)

TABLE 8-9. CAPITAL INVESTMENT COSTS (1972*) FOR UNIT #3 AND THE WATER DEAERATION TANKS AND ROOM AT ZURICH: HAGENHOLZ

Furnaces and boiler (Martin contract chute to stack)	SF 11,430,437
Spare parts**	11,374
Deaeration tanks (2)	339,837
Foundation work	548,281
Piling	43,894
Temporary office building	17,776
Scaffolding rental	9,415
Demolition and boring	96,242
Front wall, trusses, insulation	95,734
Steel structure	110,574
Heating/cooling/electrical/plumbing	125,628
Inside finishing	97,767
Miscellaneous	43,323
Photography and brochures	6,294
Engineering fee	107,453
Architect fee	58,373
Other expert fees	1,605
Interest during construction	800,015
Water treatment room	62,314
Total Capital Investment for Unit #3	SF 14,006,335
Reserve	650,000
Miscellaneous	521,665
Total Amount Financed	15,178,000

*75% of the capital costs were paid in 1972.

**However, the spare parts inventory stored in the basement under the truck repair garage now totals about SF 1,000,000.

TABLE 8-10. ANNUAL 1976 OPERATING, MAINTENANCE, INTEREST, AND OTHER COSTS FOR ZURICH: HAGENHOLZ UNITS #1, #2, AND #3

	Component	Totals
Interest	2,365,967	2,365,967
Plant Amortization	6,731,680	
Office Equipment Amortization	19,186	
Spare Parts Amortization	110,205	
Total Amortization		6,861,071
Office Wages	148,323	
Managerial Wages	162,278	
Part-time Wages	4,146	
Plant Wages	1,576,561	
Total Wages		1,891,307
Managerial Bonus	2,737	
Plant Bonus	17,617	
Total Bonus		20,354
Overalls and Clothing		8,306
Cafeteria Subsidy		16,540
Cost of Living Pension Adj.	79,258	
Planned Pension	124,798	
Makeup Pension	99,198	
Social Security Pension	92,405	
Total Pension		395,659
Accident and Sickness Insurance		35,748
Office Supplies		422
Ash Research and Treatment (net cost)		1,374,782
Other Dept. Services		14,825
Studies		994
Building	60,271	
Chute to Stack	680,809	
Ash Truck (1)	1,077	
Landscape on Old Landfill	60,697	
Workman Clean-Up Room	4,989	
Plant Controls (est.)	42,629	
Boiler Cleaning (est.)	80,000	
Cafeteria Repairs and Cleaning	5,008	
Total Repairs (no wages)		935,483

TABLE 8-10. (Continued)

	Component	Totals
Janitorial Service (est.)	3,000	
Heating (est.)	2,973	
Office and Repair Shops		5,973
Cleaning Supplies		11,861
Fuel Oil	19,217	
Electricity Purchase	105,949	
Water	201,821	
Electricity for Office	184	
Total Utilities		327,173
Truck TBA and Diesel Oil		790
Oil and Lubricants for Plant		11,223
Electrical Replacements (Lamps)		10,440
Chemicals for Water Treatment		15,332
Office Costs Burden		30,773
Property and Liability Insurance		75,151
Tax Overpayment		(3,465)
Hospitality		2,849
Damages not covered by Insurance		4,098
GRAND TOTAL COSTS		SF 14,414,893

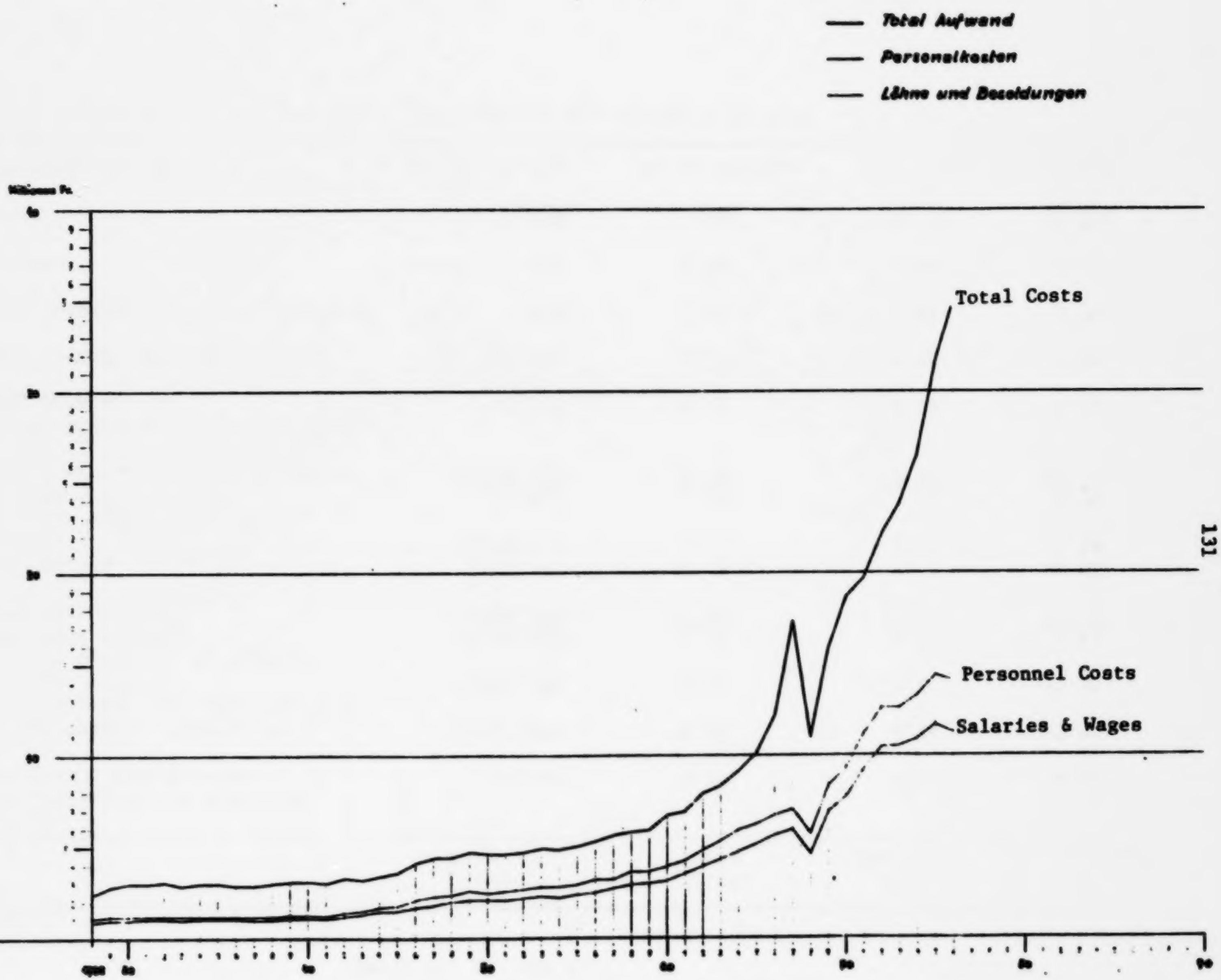

FIGURE 8-46. COSTS OF ZURICH CLEANSING DEPARTMENT SINCE 19

TABLE 8-11. ANNUAL 1976 REVENUES FOR ZURICH: HAGENHOLZ
UNITS #1, #2, AND #3

	Annual Total SF	SF per Tonne	1976 $ per Tonne*	% of rev. or costs
Rent paid by Widmer and Ernst for use of City's Tire Shredder	64,000	0.29	0.10	0.41
Citizen and Business Tipping Fee	4,032,685	18.54	6.74	27.95
Comm. and Ind. and Apt. Container Fee City trucks pick up	2,210,966	10.17	3.70	15.35
Portion of General Tax to dispose of household refuse	1,385,303	6.37	2.32	9.62
Total Tipping Fee	7,628,956	35.08	12.76	52.92
District Heating	5,057,987	23.25	8.45	35.05
Electricity	1,036,155	4.76	1.73	7.18
Ferrous Scrap Sale (containers) never burned	14,813	.07	0.02	0.08
Total Energy and Materials Sales	6,108,956	28.08	10.20	42.31
Credit for repairs to other City Dept. trucks, motors, etc.	45,951	0.21	0.08	0.33
Insurance payment for turbine break	553,941	2.55	0.93	3.86
Refund on personnel accident insurance	4,999	0.02	0.01	0.04
Miscellaneous	27,129	0.12	0.04	0.17
Adjustment	(9,670)	(0.04)	(0.01)	(0.04)
GRAND TOTAL REVENUES	SF 14,424,262	SF 66.31/Tonne	$24.11/Ton	100.00%

*At 1976 U.S. $ = 2.50 SF and 1.1 Tons = 1.0 Tonnes, i.e., divide SF by 2.75

The question was asked, "Why would you charge outsiders only SF 23.46/refuse tonne and charge your own taxpayers SF 44.57/refuse tonne--almost twice as much?" The answer was three-fold and is paraphrased as follows:

> Answer 1. "Hagenholz is an energy plant and we need as much fuel as possible. Even though the tipping fee is half, we are still being paid to accept fuel."
>
> Answer 2. "The non-Abfuhrwesen waste typically has a desirable higher heating value" (bad for Units #1 and #2, good for Unit #3)
>
> Answer 3. With more waste, our fixed costs are spread over more refuse tonnes and total unit costs will be less. The SF 44.57/tonne figure would be higher if others were to not bring waste to Hagenholz.

The scrap iron collected in plant containers before burning is sold for about SF 3.50 to SF 4.00 per ton which is about one cubic meter.

The revenue table has no entry for sale of ash residue--either ferrous or road building material. This is because the ash processing is operated separately. The result is a "net cost" and that is recorded in the annual cost table.

Both the 1976 annual costs and revenues are summarized below:

Annual Revenue	SF 14,424,262
Annual Cost	14,414,893
Net Profit	SF 9,369

A net profit figure is somewhat ficticious because of the subsidy calculation designed to make net profit come out to near zero. This deductive subsidy figure appears in the revenue table as "portion of general tax to dispose of household refuse".

As is typical of RFSG plants that manufacture both electricity and district heating; most of the energy revenues come from district heating-35% less from electricity-7% and very little from scrap metal pulled from the refuse stream before burning.

Comment: As Battelle staff has viewed systems in many countries, usually energy economics strongly favors sale of energy for district heating (and perhaps cooling for the summer load). This is in contrast to the competitive electricity prices normally held down by economical production at very large (100 times the mw size) hydro, fossil, or nuclear power plants.

FINANCE

The original 1969 development of SF 56 million was financed by three sources of funds as follows:

70% by the City of Zurich

15% by the Kanton (state) of Zurich

15% by the Federal Switzerland Government

The City of Zurich for its 70% portion put up cash on hand and also borrowed money from local banks as general obligation bonds. Usually the term is five years. The interest rate varies. Having started at 4-1/2% in 1973 for Unit #3, it was 4-3/4 in 1976. The building is amortized over 25 years and the mechanical equipment is amortized in 14 years.

Borrowing from the Swiss Federal Government carries a small but important risk. The only way that the Federal funds will be released to the City is after the plant has been built and the environmental portion of the compliance test has been successfully passed.

At Hagenholz, the acceptance test was run after 4,000 hours and before cleaning to ensure performance even under adverse conditions. As was stated, and we paraphrase again, "Anyone can make a unit be acceptable immediately after cleaning. The trick is to make it acceptable after a half year's operation with no cleaning and overhaul."

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CONVERSION FACTORS

English Units Versus SI (and Metric) Units

To Convert From	To Get	Multiply by	To Convert From	To Get	Multiply by
feet	meters	0.3048	meters	feet	3.281
square feet	square meters	0.0929	square meters	square feet	10.76
cubic feet	cubic meters	0.0283	cubic meters	cubic feet	35.31
inches	millimeters	25.4	millimeters	inches	0.0394
cubic yards	cubic meters	0.7646	cubic meters	cubic yards	1.308
barrels (oil)	cubic meters	0.15899	cubic meters	barrels (oil)	6.290
miles	kilometers	1.609	kilometers	miles	0.6214
square miles	square kilometers	2.589	square kilometers	square miles	0.3861
acres	square kilometers	0.004047	square kilometers	acres	247.1
acres	hectares	0.4047	hectares	acres	2.471
gallons	cubic meters	0.003785	cubic meters	gallons	264.2
ton (short)	tonne (metric)	0.9078	tonne (metric)	ton (short)	1.102
pounds	grams	454	grams	pounds	0.002046
grains	grams	0.0648	grams	grains	15.42

Revised Dec. 78

CONVERSION FACTORS

English Units Versus SI (and Metric) Units

To Convert From	To Get	Multiply by	To Convert From	To Get	Multiply by
pounds per million Btu	nanograms per Joule	499.2	nanograms per Joule	pounds per million Btu	0.0023
pounds per million Btu	milligrams per megajoule	499.2	milligrams per megajoule	pounds per million Btu	0.00233
cubic feet per minute	cubic meters per hour	1.699	cubic meters per hour	cubic feet per minute	0.588
gallons per minute	liters per minute	3.785	liters per minute	gallons per minute	0.264
pounds per square foot	kilograms per square meter	703.1	kilograms per square meter	pounds per square foot	0.001422
pounds per square inch	kilograms per square centimeter	0.07031	kilograms per square centimeter	pounds per square inch	14.223
pounds per square inch	atmospheres	0.0681	atmospheres	pounds per square inch	14.69
pounds per square inch	newtons per square meter	6894.8	newtons per square meter	pounds per square inch	0.00014
pounds per square inch	kilopascals	6.8948	kilopascals	pounds per square inch	0.1450
atmospheres	bars	1.0133	bars	atmospheres	0.9869
atmospheres	kilopascals	101.3	kilopascals	atmospheres	0.0098
pounds per square inch	bars	0.06895	bars	pounds per square inch	14.50
inches of water	pascals	249.08	pascals	inches of water	0.004015
millimeters of water	pascals	9.806	pascals	millimeters of water	0.102

CONVERSION FACTORS

English Units Versus SI (and Metric) Units

To Convert From	To Get	Multiply by	To Convert From	To Get	Multiply by
Btu	kilocalorie	0.252	kilocalorie	Btu	3.968
MBtu	Gcal	0.252	Gcal	MBtu	3.968
Btu	kilowatt-hours	0.000293	kilowatt-hours	Btu	3414
Btu	Joules	1055.1	Joules	Btu	0.000948
Btu per pound	kilocalories per kilogram	0.5555	kilocalories per kilogram	Btu per pound	1.8
Btu per pound	Joules per kilogram	2326	Joules per kilogram	Btu per pound	0.00430
Btu per hour	watts	0.29307	watts	Btu per hour	3.413
Btu per sq ft-hr	kilocalories per sq meter-hr	2.711	kilocalories per sq meter-hr	Btu per sq ft-hr	0.3688
Btu per cu ft-hr	kilocalories per cu meter-hr	8.897	kilocalories per cu meter-hr	Btu per cu ft-hr	0.112
pounds per 1000 pounds(gas)	grams per cu meter	1.205	grams per cu meter (gas)	pounds per 1000 pounds	0.93
grains per cu ft (68 F)	grams per cu meter (20 C)	2.28	grams per cu meter (20 C)	grains per cu ft (68 F)	0.43

Revised Dec. 78

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*U.S. GOVERNMENT PRINTING OFFICE: 1979 620-007/6305 1-3